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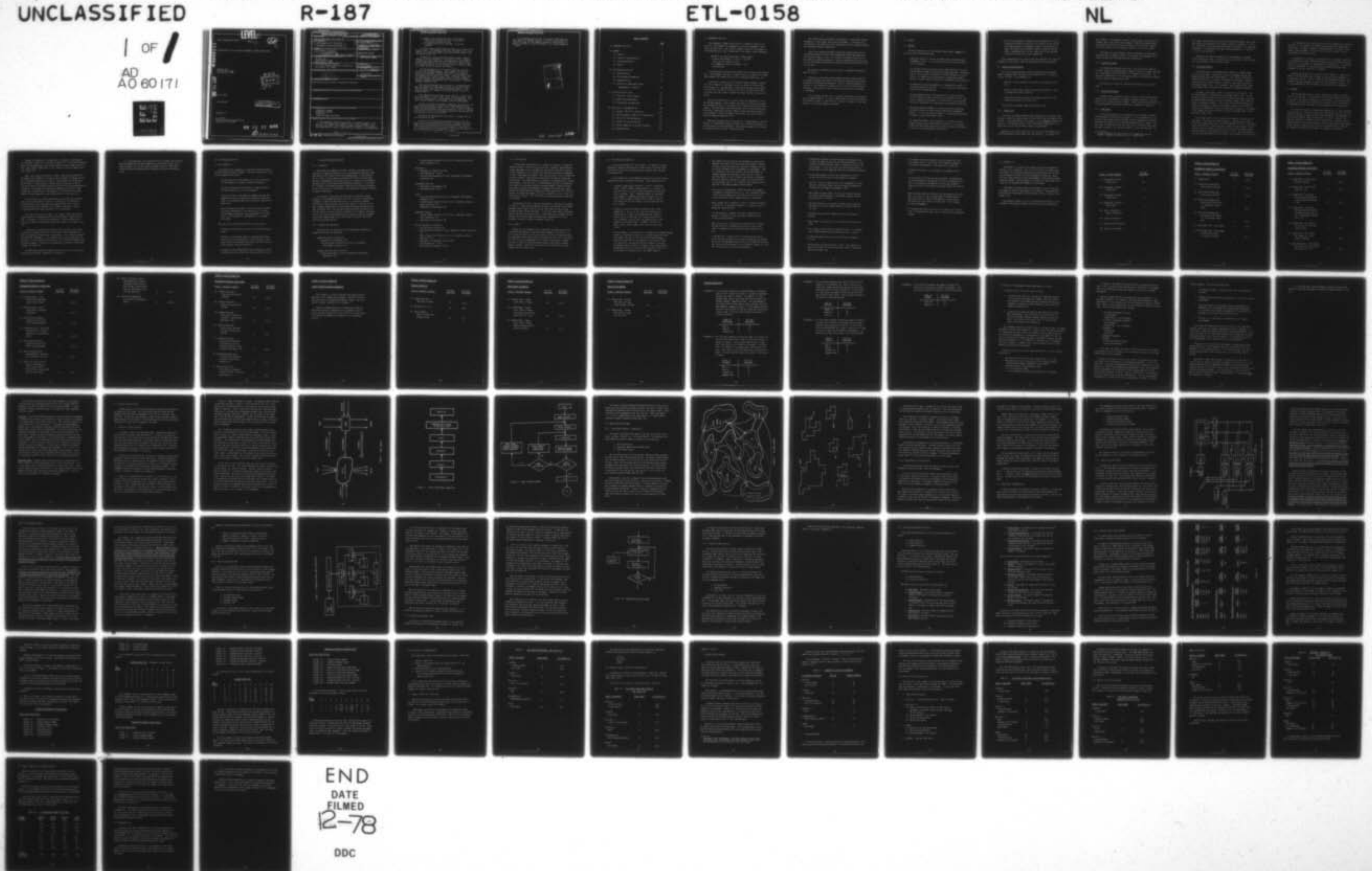

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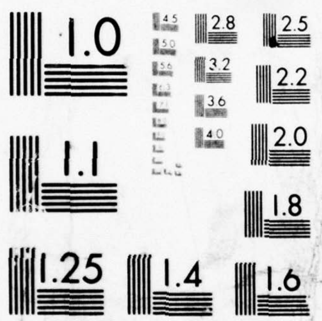

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SYSTEM ANALYSIS OF THE ENTIRE TOPOGRAPHIC SUPPORT SYSTEM (TSS)

DECILOG, INC.
555 Broadhollow Road
Melville, NY 11746

15 July 1978

Interim Report

Prepared for:

U. S. ARMY
Engineer Topographic Laboratories
Fort Belvoir, VA 22060

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Topographic Support System (TSS) is intended to supply all of the Army's requirements for topographic and military geographic information during a short, high intensity combat situation. The purpose of the System Analysis, which is described in this report, was to determine: cont

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REPORT DOCUMENTATION PAGE

- whether or not the TSS had over or under capacity
- to locate "bottlenecks", (if any), in the TSS which restrict production flow
- to recommend solutions to problems, if any were detected.

A discrete events System Simulation Model was utilized as the analysis tool. The language is one that is commonly used in the analysis of large-scale assembly and production facilities, warehousing operations, etc.

A "scenario", consisting of 39 different product requests, together with their frequency of occurrence, priority, number of originals and final copies, etc., was generated. These product requests were entered into the TSS at the rate of three per hour for a 144-hour period, both to simulate the high intensity combat environment and also to stress the system.

The TSS configuration, as of January 1978, was simulated utilizing the CDC 6600 computer. Under capacity was found in Drafting and throughput problems were found in the production of products which utilize aerial imagery. Drafting capacity was then doubled, and the under capacity was eliminated. Doubling of two other Modules, containing photo processing type equipments, improved throughput considerably, but did not result in achieving adequate production rates.

Upon detailed examination of the results, it became apparent that the problem with Image Based Products resulted from intermediate products recycling through the same equipments. Often these equipments were located in different Modules, further increasing delays.

Minor modifications were made to four Modules, in some cases, adding equipments, in other cases, merely moving equipments. Simulating this configuration, the production of the Image Based Products improved markedly, but throughput remained unacceptable.

Finally, an Interactive Graphics System was substituted for one of the drafting modules, an Analytical Stereoplotter Module was added, and the simulation, again, re-run. The Interactive Graphics had no significant effect on drafting production. Analysis revealed that this was a result of the assumption made that the TSS would not be provided with a digital data base.

The Analytical Stereoplotter significantly increased the Production Rate of the TSS.

Although the simulations were equipment-oriented, detailed analysis of the data indicated that some of the remaining problems might be due to personnel distributions and procedures. The July 1978 configuration of the TSS will be simulated in a model which will allow re-distribution of personnel. The results of these simulations should show an improvement in throughput.

REPORT DOCUMENTATION PAGE

It is concluded that the TSS, as currently configured, can meet some quick response requests. With major reconfiguration, which would make the TSS product-oriented, it should be able to meet all requests in less than 48 hours in an intense combat environment.

TABLE OF CONTENTS

1.0 Management Overview

The Topographic Support System (TSS) is intended to supply all of the Army's requirements for topographic and military geographic information during a short, high intensity combat situation. The purpose of the System Analysis, which is described in this report, was to determine:

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2.0 Summary

2.1 The TSS

The TSS was defined as a rapid response combat support system, consisting of the following subsystems:

- Operations which will provide the administrative and operational management of TSS. It will also be the entry and delivery point for all requests.

- The Storage, Retrieval and Distribution (SRD) Subsystem will house the data bank of general and special purpose topographic information. SRD will also maintain a stockpile of finished products for distribution. The remaining five subsystems are operational elements which will perform specific functions of topographic data production.

- The Reproduction Subsystem (REPRO) will reproduce the outputs in the volume required by the user. It will also reprint the stocked products which become depleted.

- The Cartographic Revision (CR) Subsystem will convert the manuscripts prepared by other subsystems into reproducible form. New data for updating the graphics in the data bank will be delivered to CR for incorporation into manuscripts or reproduction materials.

- The Survey Subsystem (SURVEY) will acquire and store coordinate and azimuth values for control points required for topographic support. It will also have the capability to determine coordinates for specific points identified by users.

- The Image Base Products (IBP) subsystem will perform all photographic processing and transformations required. This includes differential and frame rectification, mosaicking and scale changes as well as routine photographic reproduction.

- The Military Geographic Information (MGI) Subsystem will be the storehouse and center for analysis and synthesis for the terrain intelligence aspects of topographic support. The outputs will range from simple direct answers to specific questions through graphic representations of terrain conditions to full analyses of terrain for specified military operations.

Each subsystem consists of one or more vans (Modules) for a total of 23 Modules in the January, 1978 TSS configuration which was analyzed.

2.2 Inputs to System Analysis

As will be discussed below, a General Purpose Simulation System (GPSS V) computer model was used for the System Analysis. In order to utilize this tool, it was necessary to:

- Develop a list of Products and Services to be produced by the TSS.
- Manually prepare flow diagrams of each step performed in order to produce the Product or Service.
- Determine the Mean time required to complete each step in the process and variability of that time.

The following paragraphs summarize these activities.

2.2.1 Product List

A review of the Defense Mapping Agency Approved List of Products and Services revealed the general types of output which should be expected from the TSS. It was then necessary to prepare a list of specific products and services. By preparing lists of Primary and Secondary categories of request type, a list of 39 different requests was generated.

Based not only on past experience, but also on the TSS capabilities, a fixed percentage of each request was then generated. For example, Pri-

mary Category 1, "Cartographic Products - Single Level", occurs 50% of all requests, and, within that Primary Category, "Overprinted Standard Map" - using overlay from MGI occurs 2% of the 50% or 1% of the total requests. The entire Product List is presented in Section 3.2.2 of this report.

The product list was reviewed by many cartographic and user experts. No one was able to suggest a better list, however, the percentage of requests for Reprints of Standard Maps was controversial.

2.2.2 Product Attributes

All products were assigned attributes, such as Priority, Number of Originals required to produce product, Number of Copies of Product required, etc. Associated with each attribute is a frequency of occurrence. By taking all combinations of the 39 requests and their attributes over 20,000 different specific requests could occur.

The attribute list was also reviewed by many experts, and no fault found.

2.2.3 Manual Flow Diagrams

For each of the 39 products, manual flow charts were prepared showing each and every step necessary to produce a product or service. The flow charts for all products occupy 76 pages. These flow charts and times for two TSS configurations simulated are contained in Appendices A through G.*

2.2.4 Task Timing

For each task required in the production of all products, accurate time-to-complete information was necessary. For many mundane tasks, such as setting up a press and printing maps accurate information was readily available from sources such as the Defense Mapping School. However, for many tasks of importance to the TSS, particularly in the MGI area, there was great variance in the opinion of experts in the times required. For

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* Interested readers may obtain copies of all Appendices from the Engineer Topographic Laboratories, Attn: USAETL-TD-SC.

this reason, detailed definitions of such tasks were developed, and a great many sources were contacted in an attempt to obtain a concensus. In this way, times were finally developed and reviewed by personnel in a wide range of agencies. The concensus times were found acceptable by all, and were utilized in the simulation.

Because of the great care devoted to the development of accurate timing information, there is no doubt that the times used in the simulation are valid estimates of the real world times.

2.3 The System Analysis

The System Analysis was accomplished by means of a computer-based discrete system model. The specific simulation language used was the General Purpose Simulation System (GPSS V). This system is designed to develop statistics on utilization of equipment and personnel, lengths of times required to produce products, lengths of times spent waiting for available equipment, etc. It is frequently used to determine the number of equipments need in manufacturing, assembly or warehousing operations.

The model is described in detail in Section 4 of this report. The following, however, illustrates the system model capabilities. In the simulations reported herein, one of the 39 requests was chosen, utilizing one random number generator to select a Primary Category, and a second to select the Secondary Category. That request then entered the Operations Module for processing. Based upon the request category and attributes, a Route Control Generator "told" the request where to go next. For example, if the request could be met by merely retrieving a Standard Map, the request was routed to SRD.

Within each Module a similar Route Control Generator "moved" the request about. Continuing the simple example of a Standard Map, a server in the Distribution Module would utilize the Rolodex file for a time sampled from a distribution of times required to locate the required map. Having found the location, another distribution of times would be used to determine the length of time required to retrieve it, etc. The times required, of course, are modulated by the attributes, such as number of originals, etc.

If a request arrived in Distribution while all personnel were otherwise occupied, or, for example, the Rolodex was being used, the request would have to wait in a queue. Whenever a queue developed, the highest priority requests took precedence in line to the high priority, which, in turn, went ahead of the normal priority.

The example of a retrieval of a Standard Map is, of course, simplistic. In the production of more complicated products, very much longer times are required, as, for example, in cartographically enhancing MGI. It is obvious that any "bottlenecks" in the TSS would be detected where high queues developed in any area, Drafting, for example.

Because the TSS was built up from an overall model of it, down to the models of the Modules and then to models of the individual equipments, it is completely flexible. That is, where any queue developed, capacity could be added, and the simulation run again until the problem was solved. This is how recommendations were developed to solve problems of undercapacity.

2.4 Results

The TSS configuration as of January 1978 was simulated at a request rate of three per hour. Two twelve-hour shifts were simulated for 144 hours or six days. Two areas of undercapacity were detected. One was the Drafting Module, while the other involved several modules used in the production of Image Based Products combined with the preparation of Synthesized MGI.

At the end of 144 hours, Drafting had completed only 11 jobs, averaging 18.5 hours per job. There was a queue of 21 jobs waiting for drafting. The simulation was then run again with two Drafting Modules. Not unexpectedly, 22 jobs were completed, each averaging about 18.4 hours. However, the queue was dramatically reduced to only 6 jobs waiting. There was, however, underutilization of the drafting tables in Drafting when Drafting was doubled. Further analysis revealed that this was due to understaffing in Drafting. By increasing the number of draftsmen, this problem is eliminated.

Average utilizations of the Light Table in Synthesis, the Automatic Film Processor in Rectifier I, and APPS in Rectifier II, the Photo Processing Machine in Photomechanical, and the Copy Camera in Camera ranged from 67 to 96%. Queue lengths ranged from 11 to 21, except for the Copy Camera which had a queue of 55.

Again, the simulation was then run again, simply doubling Rectifier I and Camera, which appeared to be causing the bottleneck. Although the number of completed products was up sharply, queue lengths did not decrease significantly. Further analysis revealed that this was due to the recycling of several intermediate products through the various photoprocessing equipments. For example, an Uncontrolled Photomosaic cycles six times through the Printer/Enlarger, the Automatic Film Processor and the Copy Camera to produce negatives, wrong reading positives, positives, etc.

For this reason, a slight reconfiguration of the TSS was introduced. One Light Table was added to Synthesis; an Automatic Film Processor, a Printer/Enlarger and a Copy Camera were added to Rectifier II; and a Printer/Enlarger and an Automatic Film Processor were added to Camera. It was determined that these equipments fit in the Modules.

The simulation was then run again. All queues, except the photoprocessing machine in Photomechanical and the Copy Camera in Camera went to zero. The number of Single Level Photographic Products completed went from zero to 38.7% of an Expected Value of 60%, based on a no queue situation.

In addition, the same TSS configuration was simulated, substituting an Interactive Graphics System for one of the two Drafting Modules and adding an Analytical Stereoplotter to Orthophoto. The Interactive Graphics did not affect throughput. It was assumed that no digital data base was available. If this assumption is incorrect, the Interactive Graphics might increase throughput. The Analytical Stereoplotter resulted in significant increases in Production.

The GPSS Report Generator Computer Output for the four configurations simulated are contained in Appendix H-1 through H-4.

It is concluded that, with reconfiguration of equipment and personnel above and beyond that already accomplished, the TSS would have a quick reaction capability in a high intensity combat situation. Additional simulation should be accomplished to determine the required reconfiguration.

3.0 TSS Procedures and Flow

3.1 Data Gathering

Data gathering was preceding by study and discussion aimed at "fixing" TSS operational philosophy. This activity resulted in the following general conclusions:

* The major portion of TSS capacity will likely be devoted to the preparation of special purpose MGI products;

* To meet anticipated time constraints, already available MGI factor overlays are a virtual necessity;

* Time restrictions in the combat environment preclude the preparation of output products as elaborate as those produced in the peacetime base plant or garrison type environments; and

* Since no means are provided to allow utilization of panoramic aerial photography in the compilation of line maps and orthogonal photographs, such photography will be used solely in the production of photomosaics, to the extent practicable.

Data gathering included determination of the following:

* Procedures and production flow for all anticipated TSS products;

* Estimates of the average time(s) to complete each manual function, the times expressed in either man-hours or total hours based on the manning figure established for the particular module(s) under consideration;

* Estimates of the average machine and/or man/machine time(s) as applicable to the function(s) under consideration; and

* Estimated equipment downtime.

3.1.1 Procedures

Data gathering procedures included: personal interviews and discussions with recognized experts in the various mapping functional areas applicable to TSS; review of available documentation, including pertinent U. S. Army training manuals, personnel proficiency criteria, manufacturer's documentation and technical studies; inspection of equipments; and observation of both manual and man/machine operations. In virtually all instances, the average estimated times derived from these procedures, either individually or in combination, were based upon the expert opinions of several individuals.

In the areas of map compilation and special purpose MGI product synthesis it was deemed appropriate to think in terms of a hypothetical "average" 1:50,000 scale map sheet area (i.e. an area of "average" difficulty in terms of terrain and cultural detail) as well as a product treatment commensurate with the demanding 48-hour maximum TSS product turnaround time. The alternative would have been to create an individual scenario for each product considered in the computer simulation. This in turn, would have reduced the total number of products processed through the computer model to the point where "stressing" the system would not have been possible.

3.1.2 Organizations Contacted

The following is a tabulation of the organizations contacted in connection with each TSS subsystem:

Command and Control (Operations)

* Department of Cartography, DMS
* Systems Concept and Definition Division, Topographic Developments Laboratory, ETL

Storage, Retrieval and Distribution

* Mapping Development Division, Topographic Developments Laboratory, ETL

* Systems Concept and Definition Division, Topographic Developments Laboratory, ETL

Reproduction

* Department of Graphic Arts, DMS
* 30th Engineer Bn. (T)(A)
* Surveying and Engineering Division, Topographic Developments Laboratory, ETL

Cartographic Revision

* Department of Cartography, DMS
* 30th Engineer Bn. (T)(A)

Survey

* Surveying and Engineering Division, Topographic Developments Laboratory, ETL
* Systems Concept and Definition Division, Topographic Developments Laboratory, ETL
* Department of Cartography, DMS

Image Base Products

* Systems Concept and Definition Division, Topographic Developments Laboratory, ETL
* Department of Cartography, DMS

Military Geographic Information

* Terrain Analysis Center, ETL
* Applications and Systems Division, Geographic Sciences Laboratory, ETL
* Data, Products and Processing Division, Geographic Sciences Laboratory, ETL
* Department of Topographic Sciences, DMS
* 30th Engineer Bn. (T)(A)
* 64th Engineer Detachment (Terrain)

3.1.3 Difficulties

At the outset of discussions in a number of instances, the expert(s) consulted found it difficult to relate to and, therefore, make production timing commitments for an "average" map area product destined to receive product treatment in line with the short maximum turnaround time demanded by TSS in the combat environment. This was particularly true in connection with the synthesis, compilation and drafting of the special purpose MGI products and, to a lesser degree, with regard to the processing of incoming user requests. This difficulty is understandable and was to be expected, since many of the available experts had been engaged in peace-time base plant and/or garrison type operations throughout the recent past, where production time estimates are based on the anticipated level of difficulty of each individual map product, and time is generally not as critical as in the tactical situation. This difficulty was overcome through a great deal of discussion.

Considerable difficulty was also encountered in the area of equipment reliability. Investigation revealed that mean time between failure (MTBF) and mean time to repair (MTR) per se was unavailable for both already fielded equipment and new equipment. It was found that annual maintenance man-hour data was available on most of the conventional equipment and this, coupled with estimates based on manufacturers documentation on "new" equipment, was used to predict equipment reliability.

3.1.4 Results

Because of the procedures used in gathering the required data, and the considerable amount of time and effort devoted to this activity, it is felt that the results are quite reliable. The most reliable estimates are undoubtedly those which relate to reproduction activities, since these activities are quite independent of the type of area mapped. Probably the least reliable are those estimates related to MGI special purpose product synthesis, compilation and drafting since these activities are somewhat new and unique to TSS.

3.2 TSS Production Assumptions

In building any model of a real system, it is necessary to make assumptions regarding the operation of that system in the real world. The results of exercising the model can be no better than the underlying assumptions.

In the formulation of the computer simulation of the TSS, certain reasonable and basic assumptions were made. These assumptions are:

* A product request begins and ends in the C & C Operations module. When a product request enters C & C, a server will plan the job or will give a verbal explanation to the customer as a product. When a requested product is completed, this product is inspected and then distributed at C & C. Thus, times to process requests from the user to the TSS and times to deliver the product to the ultimate user are not included.

* Production routing of products through the TSS is done sequentially. This is to say, tasks are performed on a product one at a time in an ordered sequence instead of performing two or more tasks on a product concurrently. Also, a product is not divided into separate parts to be worked on in different vans. A product, including its parts, always remains together and is sent to one van at a time.

* The environment in which the TSS is to operate is the SCORES (Europe) scenario, as opposed to operating in a peacetime-garrison mode. This impacts the quality level of certain products because production times must not be excessive. Thus certain synthesis, compilation, and manual drafting procedures in MGI and Cartographic Revision reflect a product of less than excellent cartographic quality but of much lower production time. This quick response is appropriate for the SCORES scenario.

* SRD, REPRO, and IBP functions are "equipment" oriented while seemingly the functions of CR and MGI are "process" oriented. In order to make the simulation consistent throughout the TSS, CR and MGI are modelled in an equipment oriented manner. That is, to perform a CR or MGI function, certain equipments are "lumped" together and assigned to that function. Then, a specified amount of time is spent at each piece of equipment, thus partitioning a function or process into discrete tasks at the equipment level. This allows all the subsystems to be modelled in the same equipment oriented manner.

* The return of repromats back to SRD from other TSS elements is assumed to be background activity. Also, repromats stocked in the TSS are assumed to be available for use at any time without delay due to their usage elsewhere in the system.

* When a product fails inspection in the C & C Operations module at the end of its production sequence, it recycles its entire production route once more.

* The time needed for frequent in-process inspections of a product is integral with the time used to perform the job on the various equipments.

* When a scribe coat is used during the production of a product, the application of a photosensitive coating to the scribe coat is included as part of the scribe coat preparation process.

* In the Rectifier I module, both film processing and rectification functions can occur at the same time because the darkroom facilities are segregated from the rest of the module by curtains. Thus the use of the darkroom facilities does not preempt or interfere with the use of the rectifying equipment.

* Although MGI personnel are cross-trained and supposedly able to move from module to module as the workload dictates, in the simulation the MGI personnel remain in the module to which they are assigned. In the real world, they would be available to backup other functions only when they are not otherwise occupied.

* In the Press modules, "driers" are incorporated in the ink so that the drying time of printed products is reduced.

* The TSS is initially supplied with a full complement of factor overlays. Additional factor overlays reflecting changes due to the effects of combat are produced in MGI.

* The production status board is to be used to record and post the present status/progress of the product requests currently being processing in the TSS.

* The IBM card punch is to be used to update the TSS inventory when materials such as standard maps are withdrawn from the TSS stock.

* Telephone (or equivalent) communications exists between all modules.

* Power, water, and supplies will be available to the TSS at all times.

* With respect to the Interactive Graphics System, it is assumed that no CONUS-prepared digital data base exists in the TSS.

* An APPS Data Base exists for the entire area of coverage of the TSS.

* The Corps Level TSS configuration is used. This complete, 23 module Corps Level TSS is positioned with a Mean of 120 meters separation between vans.

* The request rate for TSS products is three requests per hour. This request rate will stress the TSS's production capability, allowing any "bottlenecks" in the system to be identified.

* Personnel efficiency will be constant, not degraded during a shift.

* Two twelve-hour shifts per day were simulated. No degradation in TSS performance was assumed as a function of changing shifts. That is, each person, when beginning a shift was assumed to continue the work of the person he replaced without any interruption.

* Where alternate paths are available for the production of a product, the simulation logic "looked ahead" to determine which path would result in the earliest completion of the task(s). The product was then routed to fastest path. This simulates an unerring management.

* All repromats delivered to the TSS will originally be film positives. As negatives are made, they will be saved as intermediate products.

3.3 Product List

The product list contains the products which can be produced by the TSS in this simulation. This list is the result of careful study of the DMA List of Approved Products and of consultation with ETL concerning products that the TSS would be capable of producing. Along with the listed products are their percentages of occurrences and associated attributes. The percentage of occurrence for each product coincides with the expected user demand for that product.

The product attributes describe the product's priority level and the number of copies of the product to be produced. The product attributes and their percentages of occurrence are listed at the end of the product list.

The completed product list and its associated attributes list was reviewed by ETL and other agencies and was found to be satisfactory.

Product - Primary Category	Per Cent Occurrence
(1) Cartographic Products - Single Level	50
(2) Cartographic Products - Multi-Level	15
(3) Photographic Products - Single Level	8
(4) Photographic Products - Multi-Level	5
(5) Verbal Information - and/or Explanation	4
(6) Textual Information -	2
(7) Bound Volume Information -	4
(8) Special Print Request -	12

Product - Primary Category #1

Cartographic Products - Single Level

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Map -	70	A,B,C
(2) Overprinted Standard Map - Using overlay from SRD	3	A,C,D
(3) Overprinted Standard Map - Using overlay from MGI	2	A,C,D
(4) Overprinted Standard Map - Using special MGI overlay (ie. Helicopter Landing Zones)	2	A,C,D
(5) Overprinted Standard Map - Using special MGI overlay (ie. Cross Country Movement)	3	A,C,D
(6) Non-Standard Map - scale change	15	A,C,D
(7) Non-Standard Map - scale change & selective omissions (ie. contours omitted)	5	A,C,D

Product - Primary Category #2

Cartographic Products - Multi-Level

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Map - Single overlay obtained from SRD	5	A,C,D
(2) Standard Map - Single overlay compiled in MGI	10	A,C,D
(3) Standard Map - Four factor overlays obtained from SRD & interpretation performed in MGI	50	A,C,D
(4) Standard Map - Four factor overlays obtained from SRD, interpretation performed in MGI, & cartographic enhancement in CR	15	A,C,D
(5) Standard Map - With special MGI overlay (ie. Helicopter Landing Zones)	8	A,C,D
(6) Standard Map - With special MGI overlay (ie. Cross Country Movement)	2	A,C,D
(7) Non-Standard Map - Scale change, MGI overlay with information, and compilation in CR	10	A,C,D

Product - Primary Category #3

Photographic Products - Single Level

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Photos - Using unrectified frame photographs (9"x9" format)	9	A,C,D
(2) Standard Photos - Using unrectified 3" panoramic photographs	3	A,C,D
(3) Uncontrolled Photomosaic - Standard map size using 9"x9" frame photography	10	A,C,D,E
(4) Orthophoto Mosaic - Controlled photomosaic of a standard map area using frame photography	20	A,C,D,E
(5) Controlled Photomosiac - Standard map size using 9"x9" frame photography	12	A,C,D,E
(6) Special Enlarged Photo - Photographically annotated with information from MGI	12	A,C,D
(7) Photos with control points - Manually annotated horizontal control points, 9"x9" format including APPS position coordinates	12	A,C,D

(8) Photos with control points - photographically annotated horizontal control points, 9"x9" format including APPS position coordinates, also with MGI annotation	12	A,C,D
(9) Uncontrolled Photomasaic - Using unrectified panoramic photos	10	A,C,D,E

Product - Primary Category #4

Photographic Products - Multi-Level

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Photo Map - Single overlay obtained from SRD	20	A,C,D
(2) Standard Photo Map - Single overlay obtained from MGI	20	A,C,D
(3) Standard Photo Map - Single overlay obtained from SRD & interpretation performed in MGI	20	A,C,D
(4) Standard Photo Map - Single overlay obtained from SRD & two overlays from MGI	10	A,C,D
(5) Standard Photo Map - Single overlay obtained from SRD, two overlays obtained from MGI & interpretation performed by MGI	10	A,C,D
(6) Non-Standard Photo Map - Using overlay information from MGI & drafting performed by CR	10	A,C,D
(7) Standard Photo Map - Using overlay information obtained from MGI & drafting performed by CR	10	A,C,D

Product - Primary Category #5

Verbal Information and/or Explanation

This category is slightly different than those previously mentioned. This category was designed to simulate an activity that would occur in the Operations Module. Namely, the distribution of verbal information to a "customer".

Since the standard analysis of conversation length has been found to be well represented by an exponential distribution, we have selected such a distribution with a mean value of 15 minutes to represent the transmission of information verbally.

Product - Primary Category #6

Textual Information

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Bulletin - Retrieved from SRD	50	A,B,C
(2) Standard Trig. List -	20	A,B,C
(3) Special Report - Special 5-page report prepared by MGI	30	C,D

Product - Primary Category #7

Bound Volume Information

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Maps - reduce scale, $8\frac{1}{2}$"x11" format	40	A,C,D
(2) Standard Maps - reduce scale, $8\frac{1}{2}$"x11" format, including point position detail and trig. lists	25	A,C,D
(3) Standard Maps - reduce scale, $8\frac{1}{2}$"x11" format, special purpose overlay and text from MGI	35	A,C,D

Product - Primary Category #8

Special Print Request

Product - Secondary Category	Per Cent Occurrence	Associated Attributes
(1) Standard Map - produce 1000 copies of a map using repromat from SRD	75	C
(2) Standard Map - produce 1000 copies of a map with revisions	25	C

Attribute Definitions

ATTRIBUTE A: This attribute represents the desired number of different basic items of a particular nature, in a specific Secondary Category, per specific request. For example, (1) Four Standard Maps, each of which describes four different, but perhaps adjacent, topographic areas. (2) Three Standard Photo Maps, each of which depicts three different, but perhaps adjacent, topographic areas. (3) Two Standard Military Bulletins, which consist of the most recent and the one previously issued. This attribute can take on the value in the following table:

Number of Basic Items	Per Cent Occurrence
ONE (1)	75
FOUR (4)	10
SIXTEEN (16)	15

ATTRIBUTE B: This attribute represents the desired number of originals of each of the different basic items of a particular nature, in a specific request. This attribute applies only to those basic items that are distributed to "customers" in original form. For example: (1) Standard Maps, (2) Bulletins, (3) Trig. Lists, are all simply retrieved from files and distributed. This attribute can take on the values in the following table:

Number of Originals	Per Cent Occurrence
ONE (1)	80
FOUR (4)	12
SIXTEEN (16)	5
HUNDRED (100)	3

ATTRIBUTE C: This attribute represents the level of priority of the request it is associated with. Each of the priority levels will impact the service times and waiting times associated with the current transaction. Priority level will also affect the speed with which certain TSS personnel perform their duties. This attribute can take on the values in the following table:

Level of Priority	Per Cent Occurrence
NORMAL (0)	5
MEDIUM (1)	85
HIGH (2)	10

ATTRIBUTE D: This attribute represents the desired number of copies of a product resulting form a TSS processing action other than just pure retrieval/distribution. This attribute differs from ATTRIBUTE (B) in that it applies to all items exclusive of those that ATTRIBUTE (A) encompasses. This attribute can take on the values in the following table:

Number of Copies	Per Cent Occurrence
ONE (1)	80
FOUR (4)	3
SIXTEEN (16)	15
HUNDRED (100)	2

ATTRIBUTE E: This attribute represents the number of frames to be rectified in the process of making a Photomosaic. This attribute can take on the values in the following table:

Number of Frames	Per Cent Occurrence
EIGHT (8)	60
TWELVE (12)	40

3.4 Analysis of Image Based Product Requirements in the TSS

The objectives of this effort were as follows:

1. To acquire user input as to the need for image base products in the tactical environment and, thereby, verify to the extent possible, the assumptions made by DECILOG concerning the frequency of requests for these products as used in the TSS computer simulation; and

2. To specifically review the need for TSS production of orthogonal photography, since the production of such products in the TSS environment presents somewhat complex technical problems in the areas of both source input (ie. aerial photography) and processing instrumentation.

The orthophoto technical problems relate to the fact(s) that: the analog equipment, originally anticipated for integration into TSS and likely capable of withstanding the harsh physical environment, requires mapping quality, vertical aerial photography (ie. photography of high geometric fidelity); while the analytical orthophoto equipment, subsequently proposed and somewhat more susceptable - in its commercially available form - to damage in the TSS environment, is capable of utilizing both mapping quality photography and reconnaissance photography.

During the course of the study, meetings were held with the following organizations:

- Assistant Chief of Staff for Intelligence (ACSI), U. S. Army
- Requirements Division, Directorate of Plans and Requirements, Defense Mapping Agency Topographic Center (DMATC)
- Technical Director, Defense Mapping School
- U. S. Army Engineers School
- U. S. Army Combined Arms Combat Development Activity (CACDA)

In addition, the GIANT-75 study was carefully reviewed to determine what, if any, justification(s) was/were used in formulating the recommendations for TSS-produced image base products, particularly orthogonal photographs.

During the above meetings, the assumptions used by DECILOG in its TSS model simulation - with regard to the types and percentages of image base products - were discussed, and the participants were asked to express their views as to the reasonableness (or lack thereof) of DECILOG's assumptions. The following products were reviewed:

- Individual Photographs (Vertical)
  - 2x Enlargement
  - Standard Map - Size Enlargement
- Individual Photographs (Panoramic)
  - 2x Enlargement
  - Standard Map - Size Enlargement
- Photomosaic
  - Uncontrolled
  - Controlled
- Orthogonal Photograph
- Photomap
  - Using Controlled Photomosaic
  - Using Orthophotomosaic

In all cases, an attempt was made to identify the user of the product, the purpose or use of the product, and the alternative product if the image based product was not available.

Review of the GIANT-75 study did not reveal the existence of any hard justification for TSS production of orthogonal photographs. It did indicate that: "contoured orthophotographs produced with a combination of these devices (ie. Kelsh Plotter/SFOM 693 orthophotographic unit) and cartographic quality photography can be the base for multi-scaled graphics for many planning and operational purposes. However, compilation is slow and dependent on the availability of suitable photography." The study recommended incorporation of a modified van body to accommodate this type (ie. ortho-

photo) equipment. The study also noted that:

1. The enhanced photomap is produced faster than the conventional line map;

2. Photomap production requires the availability of new (ie. current) photography;

3. Since requirements for cartographic quality photography are secondary to the requirements for reconnaissance photography, it is doubtful that suitable photography will be available for photomap revision under battle conditions; and

4. Therefore, it is adviseable to standardize on the line map vice photomap.

The discussions revealed that the primary value of the image based products (particularly orthogonal photographs) was as an expedient. In no case was it found that these products were an absolute necessity. Most users indicated that the image based products were an important and highly desireable adjunct to the line map products. All indicated that the controlled photomosaic was of equal value to the orthophotomosaic.

Discussions as to the types and percentages of image based products used by DECILOG in its TSS computer simulation revealed only minor disagreement in a few cases by the user. In all such instances, the user involved indicated that he had no better basis for his estimate than did DECILOG.

Additionally, CACDA user personnel stressed the fact that maps will, in the future, be used only for mobility purposes. Artillery will utilize advanced hardware such as FIREFINDER and PADS for precision targeting. Infantry and Armor will similarly rely on laser designators and the Position Location and Reporting System. Even Intelligence will require that all mobile direction finding and other listening systems will require <u>on board</u> Position/Location hardware.

It is concluded that revised photomaps, prepared from controlled mosaics of rectified photography can replace orthophoto products in the TSS.

During recent discussions one user group suggested that orthophoto city maps might be an expedient substitute for the line maps needed in connection with Mobility Operations in Built-up Areas (MOBA). A second suggested orthophoto application was in the mapping of areas devastated by nuclear attack.

City Maps - One of the problems encountered in the use of aerial photography in mapping built-up areas is the shielding of detail located in the shadows (ie. layback areas) of buildings, trees, etc., which are not located at, or closely adjacent to, the photo center. In conventional photogrammetric mapping this is overcome by extracting the desired planimetric and topographic detail while viewing a stereo model. During the compilation of an orthogonal photograph, a stereo model is used to orient and adjust the photo image. However, during the subsequent scanning operation only one of the photographs is considered. This being the case, it appears obvious that all detail falling in the shadows will be omitted from the resultant orthophoto. It may be possible to circumvent this problem by judiciously considering other photo models of the area under consideration assuming adequate photography (ie. adequate photo coverage). This, in turn, will dictate that at least twice as many photographs must be scanned. Either the additional time required or inadequate photo coverage could result in this becoming a much less viable solution as a rapid mapping alternative.

Devastated Areas - Assuming severe devastation one must assume that the detail shown on the APPS photographs would be largely non-existant. This, in turn, would likely dictate performance of a new control survey. Since a basic mapping job would be required, it would appear prudent to allow the mappers to decide what technique would be most appropriate in line with available source materials, equipment and manpower.

4.0 System Simulation Study

A system analysis of the TSS was conducted to determine the operating performance of the system. The various specifications concerning the equipment and human resource complement of the TSS as of January, 1978 were used. The analysis was performed by means of constructing a computer-based simulation of the system. The following sections describe the design, construction of, and results produced by the model.

4.1 Simulation - Basic Concepts

In business, industry and government today, large-scale, complex projects are the rule rather than the exception. In order to minimize the high cost and risk of such projects, the planning and implementation phases must be as efficient as possible. Preliminary studies to assess the suitability of plans, before they are adopted, are thus vital to efficient and economical execution of all projects of any considerable size. One technique of performing such pilot studies, which yields reliable results while being economically tractable, is simulation.

Simulation can be described as the process of designing an algorithmic/mathematical description of a system, subsystem or process and conducting experiments with this description for the purpose of either understanding the behavior of the system, subsystem or process, or of evaluating various strategies for the operation of the system, subsystem or process. This fundamental process of designing the algorithmic/mathematical system description, is generally referred to as modelling.

A model is a representation of a system, it is not a replica; it consists of a description that may be physical, verbal or abstract in form, together with a set of operating rules. However, a basic requirement for any model is that it should describe the system is sufficient detail for the behavior of the model to provide valid predictions of the behavior of the system. More generally, the characteristics of the model must correspond to the characteristics of the system being modelled.

Figure 4.1 shows the concept of a model. The shape has been idealized to show that the model is usually a simplification of real life. Parameters specifying characteristics or attributes of both system and model appear in each case. Input to and Output from the real system have been formalized in the model and correspondence between input to both system and model have been identified. However, the two outputs do not necessarily have the same correspondence. As both the system and the model can be considered as functions that transform input to output, the output from a suitable model might be used to infer the output from the system that it represents.

For a simulation study to be truly useful, careful attention must be paid to the formulation of the basic system model. This basic system model structure will usually contain several subsystems, which, in turn, are composed of elements, whose operation are specified by certain relationships. The formulation of the system model must them proceed from the "bottom-up", as depicted in Figure 4.2, taking into account all those features from which the analyst builds up a logical structure for a simulation experiment, starting with the basic components of the system from which the "final" model is constructed. Once the first version of the "final" model is constructed, the first phase of the simulation study can begin - exercising the model that currently represents a particular portion of the system, or perhaps, the entire system itself.

At this point in the simulation study, the true value of the model is just coming into focus. The simulation/modelling process is most effective when used in an iterative fashion. One such iteration scheme is shown in Figure 4.3. A simulation experiment, based on the current state of the system model, would be run and the results produced would be analyzed. Analysis of the output would suggest modifications to the model, or the operating strategies that drive the model, and a second simulation run could be made after performing the required modifications. Thus, step by step, we gain more knowledge about the system design and its performance until there is sufficient information to make final recommendations about the system, or part thereof, to be implemented.

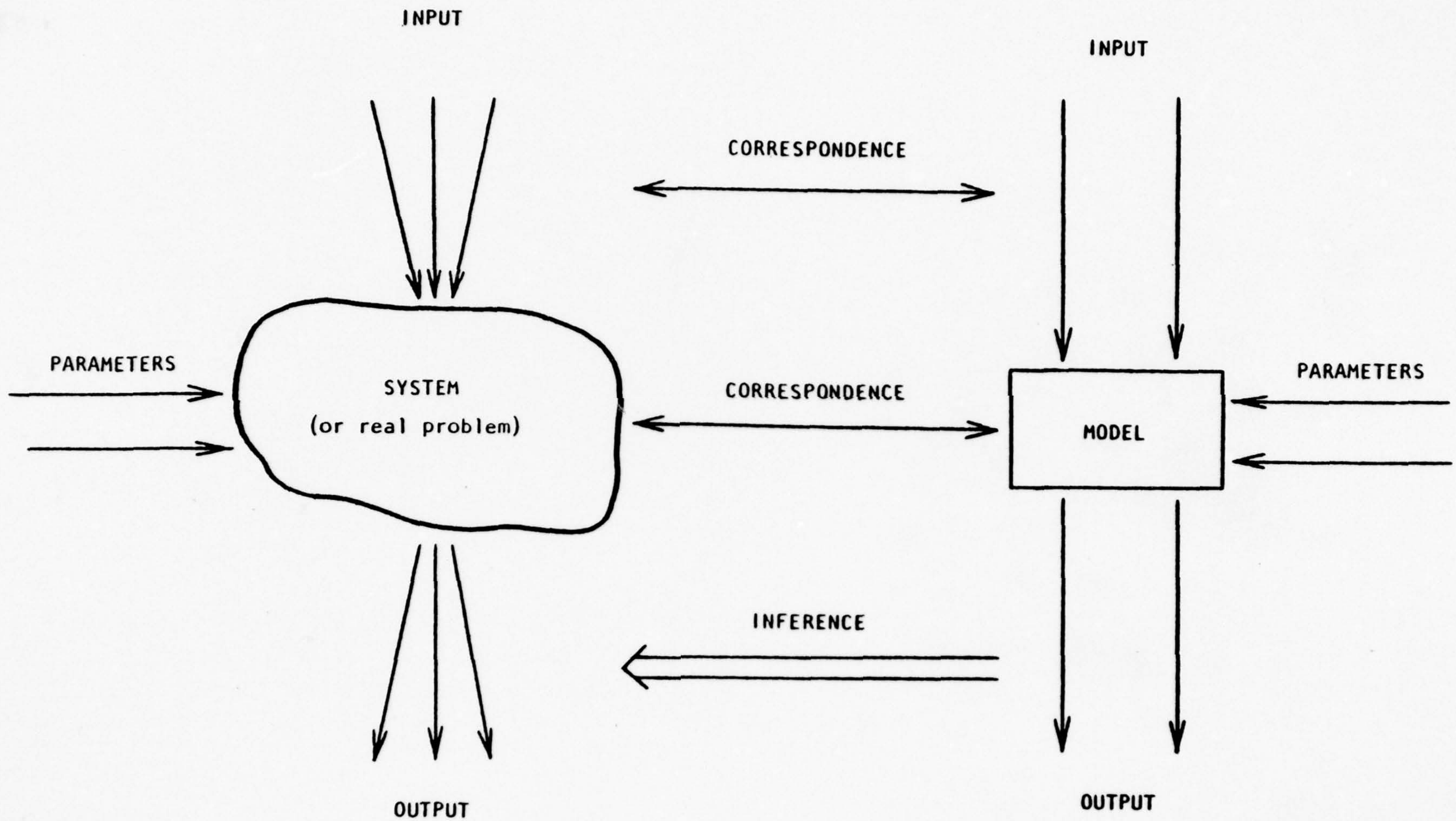


FIGURE 4.1 MODEL CONCEPT

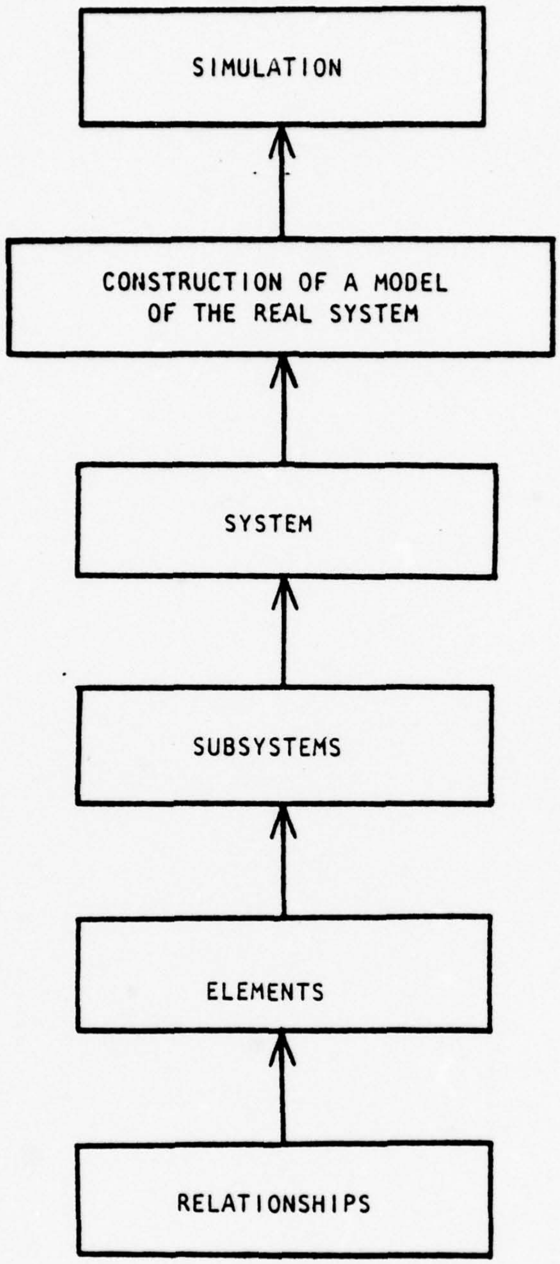


FIGURE 4.2 BASIC SYSTEM MODEL FORMULATION

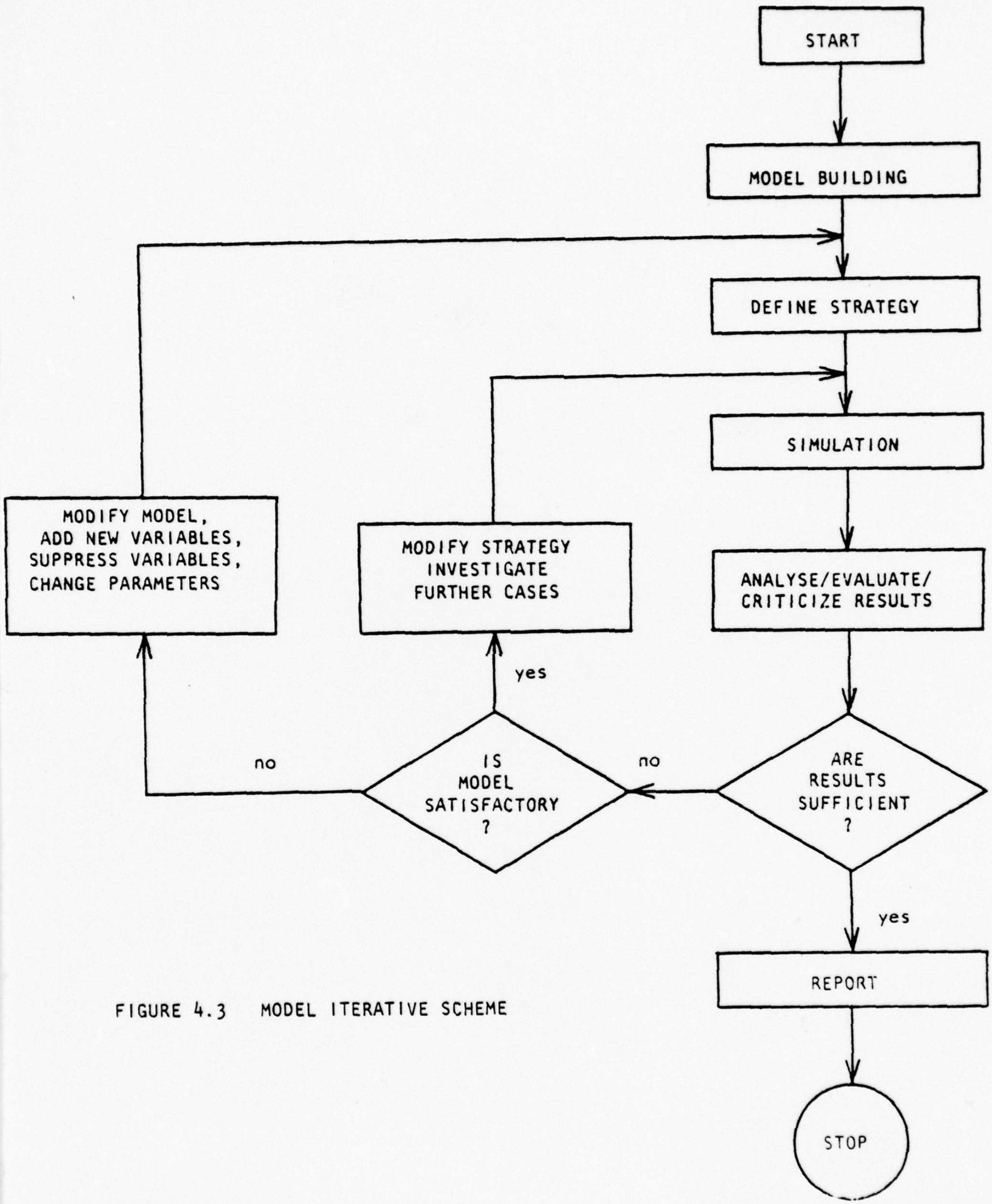


FIGURE 4.3 MODEL ITERATIVE SCHEME

This overall simulation/modelling/iteration process, allows various design decisions concerning extremely complex, and costly, systems to be evaluated and compared without having yet built the target system. Simply, simulation allows management to ask the question: "What would happen if...?" (ie. "I added another light table here?" or "I substituted an Interactive Graphics System for Drafting?", etc.)

4.2 Generalized System Model

4.2.1 System Model Content / Organization

The overall structure of the model of the TSS, as put forth in this study, is shown in Figure 4.4, in stylized fashion. The functional system elements are three in number and consist of the following:

1 - Driving Functions
2 - Subsystem, Module and Equipment Models
3 - Route Control Logic

The driving functions of the system model generate product requests and then control their paths through the TSS. For product request generation, a product request is first selected from the product distribution function. Then, the attributes describing the selected product request are generated by the product attribute distribution. With the products and their attributes chosen, the requests enter the TSS at a pace that is controlled by the inter-arrival rate function. This inter-arrival rate simulates customer demand upon the TSS.

Once entered in the TSS, a product follows a pre-determined production path through the TSS as specified in the route control matrix. Another driving function affecting TSS throughput is the van separation distance matrix because the movement between modules is impacted by the amount of distance between the modules. Figure 4.5 depicts a reasonable TSS configuration which was used to calculate the distances between modules. These inter-module distances are listed in the van separation distance matrix.

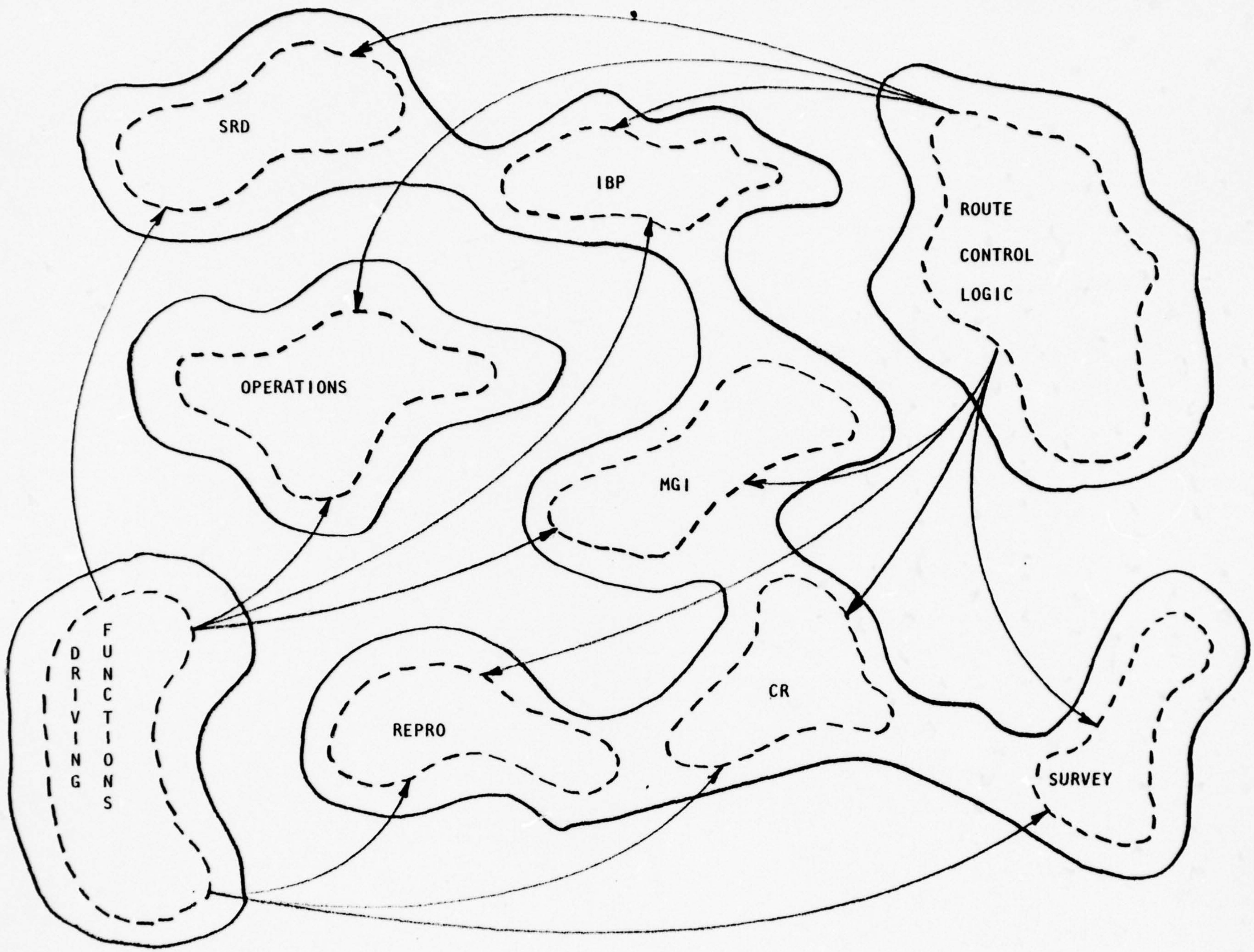


FIGURE 4.4 TSS MODEL CONCEPT

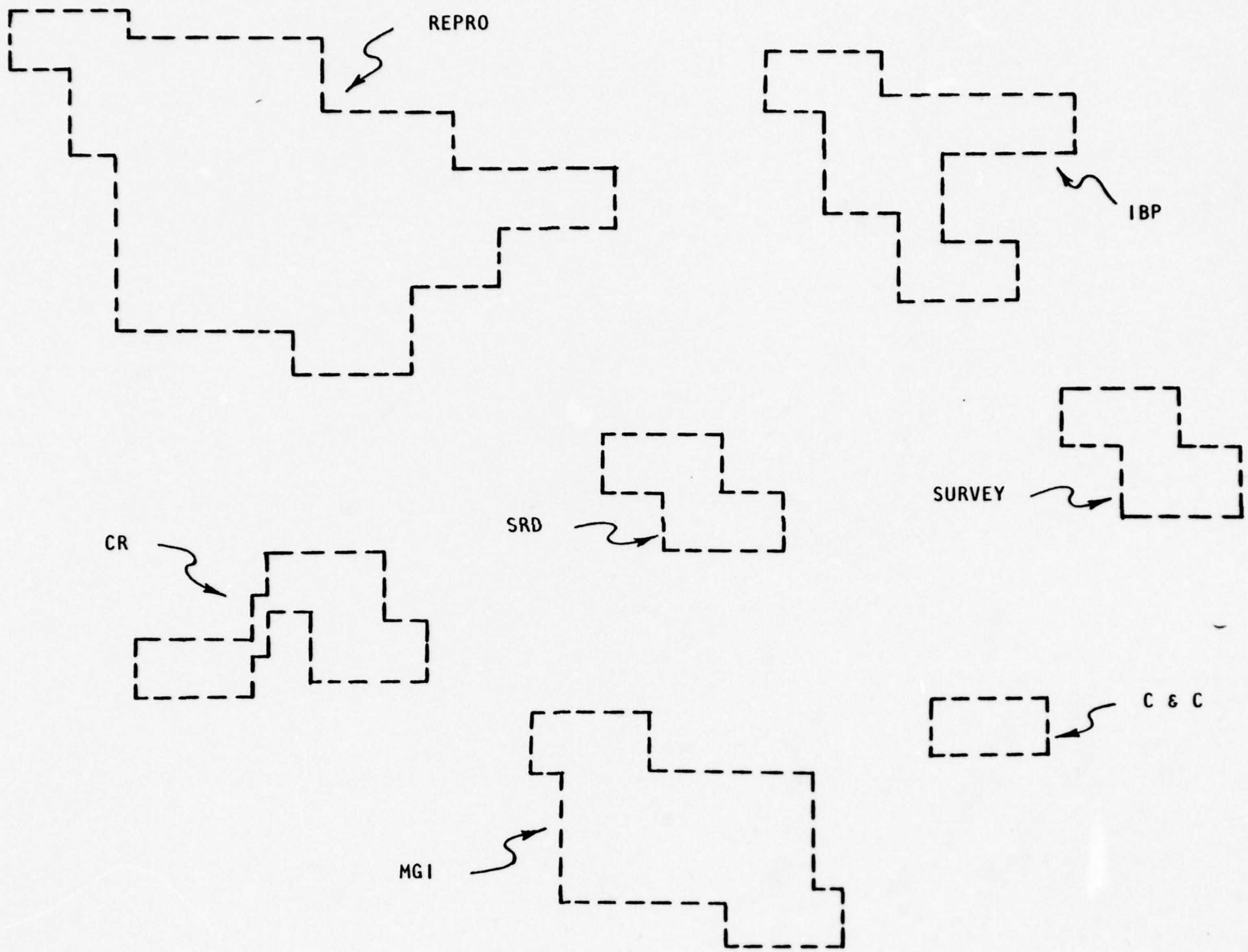


FIGURE 4.5 TSS SUBSYSTEM LAYOUT

SCALE: 1" = 100'

The route control logic is responsible for guiding the product along its pre-determined "assembly" path to completion. Thus, the system model driving functions modulate the dynamic characteristics of the TSS model.

The simulation of the physical elements of the TSS, ie. equipment, vans, etc., was done in a modular fashion. At the basic level, models were created for each piece of equipment. These equipment models were then assigned to their respective vans which, in turn, were organized according to subsystem. Also, within each van, a number of personnel is assigned. The personnel in each van are assumed to be able to operate any equipment within that van. The modularity of the system model allows for a logical organization of the TSS elements and for the capability to modify numbers, types and locations of the equipments with relative ease.

The simulation language used in the TSS System Analysis is the General Purpose Simulation System (GPSS). The GPSS simulation model of the TSS also includes specially prepared report generator subroutines that organize, summarize, tabulate and neatly present the general statistical output provided by the GPSS simulation language. The resulting summarized output reports on the status and performance of the TSS model.

4.2.2 System Model Driving Functions

In the TSS system model, there are several driving functions that dynamically control the TSS's input and throughput.

The first driving function that affects the system model's input is the product request distribution. The product request distribution is a catalog of the products that can be produced in the TSS and their probability of occurrence. This product request distribution allows there to be varying degrees of demand for different products.

The next driving function is the product attribute distribution. Each product has attributes, or characteristics such as level of priority, number of different items requested, etc., which have an impact on a product's input into the TSS and its subsequent throughput. The various product attributes each have varying numerical quantities which are ap-

portioned in a probability distribution. From this product attribute distribution then, product attritubes can be generated for each product request.

Another input driving function is the product request inter-arrival rate. This inter-arrival rate controls the number of product request that will be generated during a given time. For example, in this system model, an inter-arrival rate of three product requests per hour was used. This rate was chosen so that the TSS's capabilities would be stressed. The product request inter-arrival rate can easily be varied from simulation to simulation to reflect different loads on the TSS's production facilities.

The route control matrix is a major driving function concerning TSS product throughput. The route control matrix contains the pre-determined production paths for each product. As a product flows through the TSS on its way to becoming a finished product, it must do a route control matrix look-up for each step of its production. Thus, the route control matrix maps out a pre-determined production sequence for each product.

The van separation distance matrix also figures into TSS throughput. Given a certain TSS layout or configuration distance between each van is measured and stored in the system model's van separation distance matrix. These distances are used to reflect the travelling times of the products between vans.

It should be noted that the model is modular to the extent that all of the driving functions can be changed easily and quickly without changing the model structure. Hence, the exact same model can be driven with different function specifications so as to investigate their effect on TSS performance.

4.3 System Model Implementation

In order to preserve the flexibility naturally inherent in a simulation study, while providing for a closely parallel relationship between the functioning of the model and the actual operation of the TSS, a specialized scheme was developed for implementation of the model.

The implementation scheme focused primarily upon the integration of four types of elements into an overall TSS simulation model. These elements, or submodels, consist of the following:

1 - Operations Module Element
2 - Generalized Module Element
3 - Generalized Equipment Element
4 - Transaction Route Control Element

Incorporation of these functional system elements into the overall system model concept, immediately allowed for the dissolution of an extremely complicated system analysis and modelling task into several smaller, more tractable, tasks. Hence, from the viewpoint of simulation and modelling, the construction of an extremely complex model has been reduced to the construction of several less complex submodels. The logic, which allows those submodels to be integrated in, collectively, a model of the entire TSS.

The concepts involved in the design and implementation of each of the four elements will be discussed in the following sections.

4.3.1 Operations Module Model

The operations module forms the foundation of the entire TSS system, for it is the place where transactions (ie. requests for products) are originated, planned and finally return, when they are completed. It is, in essence, the nerve center of the TSS. The organization of its model is depicted in Figure 4.6. The following text presents the methodology with which the model was constructed and the logic by which it operates.

Since the primary TSS driving function concerns the rate at which requests for products enter the operations module, the first logical step in analyzing the operation of the TSS was to determine the inter-arrival time between "customers". More simply stated, how long is the time delay between requests for products produced by TSS? Upon examining the technical data package, speaking with appropriate personnel at ETL and appreciating the fact that the simulation will be emulating a TSS deployed in a combat situation, the assumption was made that customers will arrive

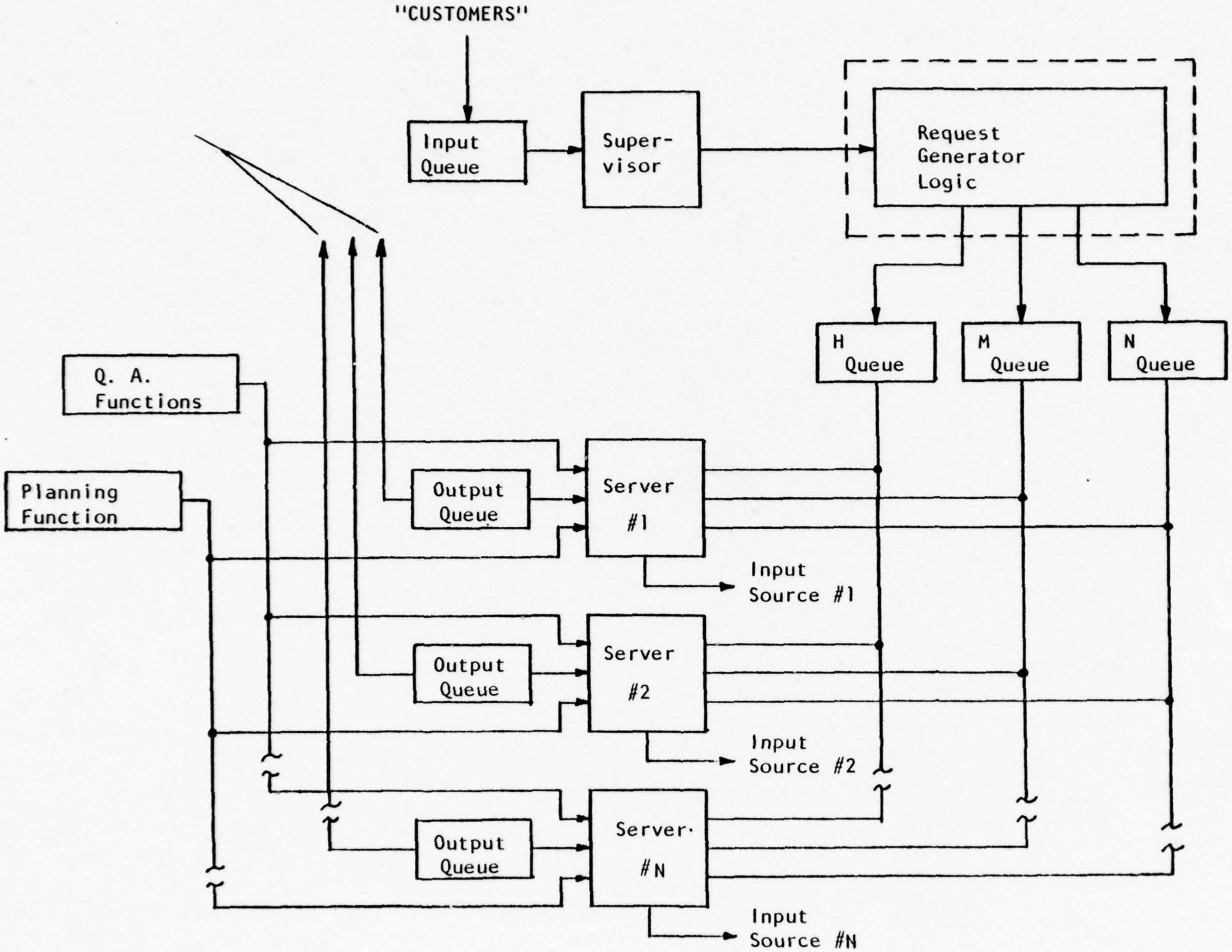


FIGURE 4.6 OPERATIONS MODEL ORGANIZATION

in a Poisson fashion with an average inter-arrival time of 20 minutes. Therefore, the GPSS implementation of the "customer" arrival would essentially involve the random sampling from the appropriate distribution and the creation of the "customer" entity. This entity will then be admitted to the customer queue. The GPSS processor will gather statistics for each queue entry as to its time of arrival, time of departure and other transactional information.

The next logical step in the operation of the TSS, is for the "customer" to converse with the operations officer (supervisor) concerning his need for an item that TSS produces. Again, examination of the technical data package and conversations with ETL staff members has allowed the development of a function that represents the "customer"/ operations officer conversation length. It has been determined that conversation length is best represented by an exponential distribution with a mean of 10 minutes. The GPSS implementation of the talk function would be similar to the implementation of the customer arrival logic. As a result, a person who "comes to the front" of the "customer" queue line will sieze the supervisor when he next comes available. GPSS will then sample from the appropriate distribution and serve the "customer" for a prescribed time interval. As a result of a customer arriving and conversing with the operations officer, the request for a specific TSS product would become apparent.

After analyzing the operational information associated with the functioning of the TSS and deciding on a modular, path oriented, model topology, the definition of the structure of requests was arrived at. Careful attention was paid in designing the request structure so as to form a realistic loading effect on the TSS. The structure of a request consists of choosing a product-primary category and appropriate values for certain attributes associated with a product. The product-primary category consists of eight types of products that the TSS is responsible for producing. The list and the per cent of time that the Operations Module would issue a particular request type is given in section three. As far as the model is concerned, the end of the conversation between a "customer" and the operations officer would trigger a sampling of the distribution of the per cent occurence of a particular product-primary category. This would result in the creation of a transaction with the

label of the category chosen.

The next step in the logic is to increase the specificity of the transaction by choosing a product-secondary category. The tables in Section 3 list the product-secondary categories, and their per cent occurrence, according to product-primary categories. Again, special care and consideration was given to the definition of these tables to preserve realism in the simulation. During the simulation a random sampling of the appropriate product-secondary category distribution resulted in the assignment of a specific secondary category to the current entity with the appropriate primary category label. Other calculations and samplings were performed which resulted in the assignment of various parameter values (ie. number of copies of a particular map, priority of request, etc.) to the current transaction. The total impact of the aforementioned activities and computations was the creation of a bonafide product/service request.

At this point, the logical flow path control through the simulation model must be assigned to the current product request. This is accomplished by retrieving the appropriate, pre-defined, path information from a storage array and assigning it to the current transaction. The transaction will then contain all the necessary information to traverse the TSS. It should be noted that the request generator and path generator have no counter parts in the TSS system. They appear in the model for the sake of uniformity and reduction in the logical complexity of the model. Also, their functions were performed in zero simulation time so that the operation of the model was realistic. It should also be noted that the tables in Section 3 include information pertaining to the request parameters (attributes). Namely, the types of attributes, the products they are associated with, the values they can assume and the distributions governing the assignment of those values.

Now that the "customer" has finished speaking with the supervisor and a bonafide request has been created, with a specified priority, GPSS will place the "customer" and his request in a queue corresponding to the priority of the request. These queues, as shown in Figure 4.6, are the high, medium and low priority queues and are entered via a buffer (traffic cop) block. Once the customer resides in a server input queue

a certain logic must be applied to determine which server will serve him. In the case where a request is for verbal information, the supervisor will personally service the customer for the sampled conversation time length.

For a moment, let us examine the output queues that feed each server as shown in Figure 4.6. These output queues correspond to the servers, (of which only three of the five are shown for clarity). These queues contain completed TSS products that must be verified for quality assurance and distributed by the appropriate server. When the request is first created by the C & C subsystem, it is tagged with the number of the server who handled it before inputting it to the TSS. When the product is completed, GPSS utilizes this tag to route the product to the output queue of the original server. The particular server will, when just becoming available, scan his output queue for residents. GPSS will make note of the highest priority present. The server will then scan the input queues to ascertain whether or not there exist any inputs of a higher priority. If there exist none, the server will be siezed by the highest priority resident in the output queue. The server will then examine the product-primary/secondary category parameters and, with the help of a quality assurance time function, perform a service for a prescribed amount of time. If there were a resident in the medium or low priority input queues, and his priority were higher than the output queue residents priority, then the server would service that customer. Again, the server having examined the customer request parameters will service the input request for a specific amount of time, prescribed by sampling from the delay function.

In the special case, where there is a resident in the high priority input queue, a preemption will occur. In essence, GPSS will interrogate the servers to determine the servers who are currently servicing input requests or output requests of priority medium or low. The first such server detected will be forced to stop (preempt) his current activity and service the high priority request. The request that was interrupted will continue to be served upon the server's completion of the high priority task. This logic discipline has been carefully prepared to as to reflect the realistic operation of the C & C subsystem.

Among the statistics which were gathered on internal TSS operations are:

* Per cent utilization of each "server" and supervisor
* Number of requests in queue for "server" by priority
* Mean and distribution of times in queue by priority
* Number of requests in queue for supervisor

Obviously, conclusions regarding the acceptable inter-arrival time of requests and the adequacy of manning within C & C can be drawn. Similarly, the logical process used to construct the model of the Operations Module has been applied to the internal operation of each of the modules in the TSS.

4.3.2 Generalized Module Model

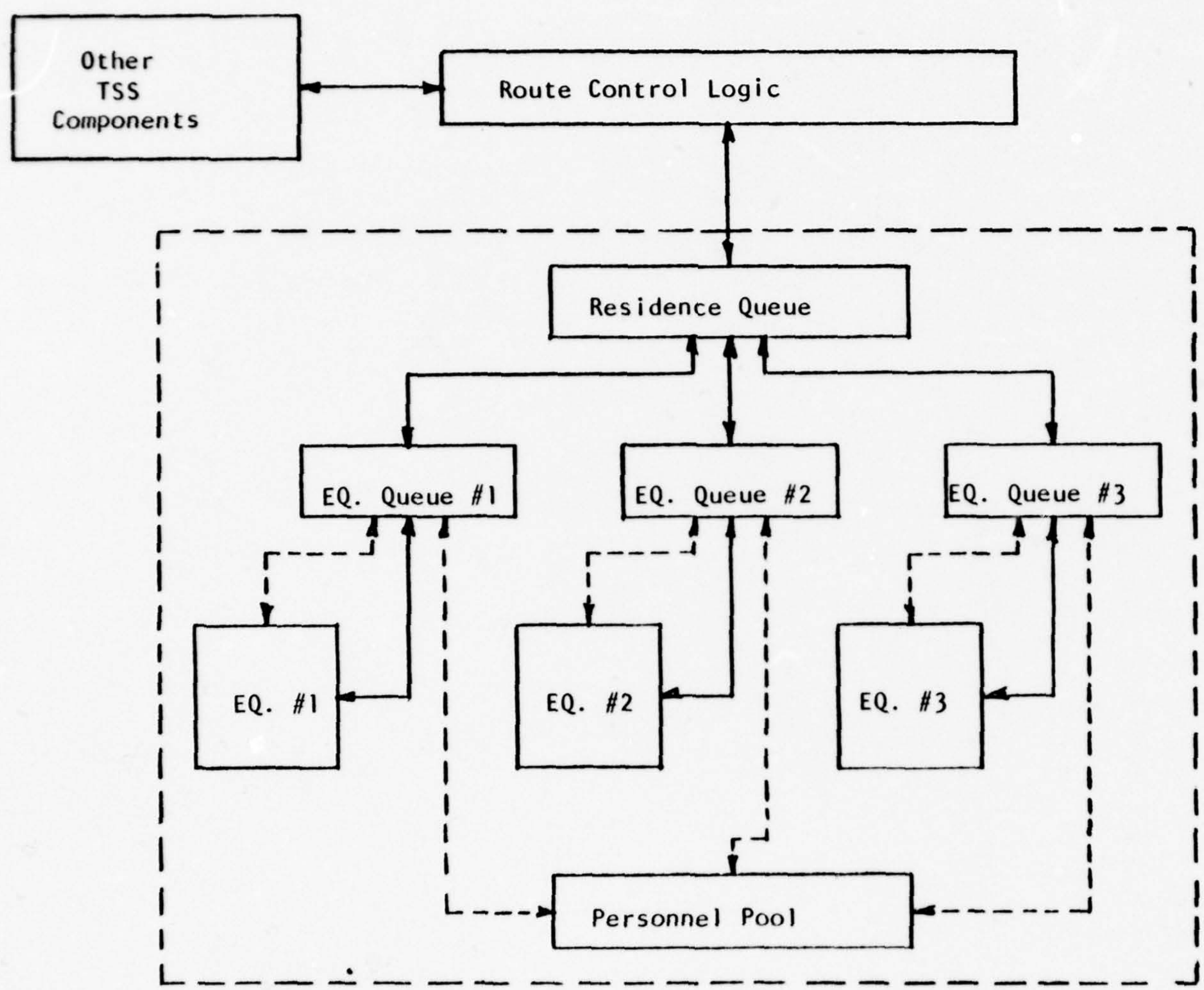
The TSS is an assemblage of modules, whose contents are people and equipment responsible for performing a particular process, or part thereof. Therefore, it was relatively easy to build a generalized module model in which the models of the specific equipments could be later included. The complicated integral model of people/equipment/van was divided into two model components, one of which is the generalized van/personnel model and the other is a model of the equipment content.

Figure 4.7 depicts the organization of the generalized module model. The module model consists of four basic entities which are:

1 - Van Residence Queue
2 - Equipment Capture Queue
3 - Equipment Models
4 - Personnel Pool

In actuality, the equipment models are not included in the van model, except for a logic interface which allows for a check of the equipment busy/free status flag.

FIGURE 4.7 GENERALIZED MODULE MODEL ORGANIZATION



The first action that occurs in the operation of the module model involves the arrival of a request for a product, or process that would result in a product, or part thereof. This request is coordinated with the other TSS components via the route control logic and entered into the specific module as set forth in the pre-determined entries of the route control matrix.

Upon entering the module, the transaction immediately enters the van residence queue. The transaction will remain in this queue until it has completed its specific tour through that module, at which time the appropriate queue statistics (see Section 4.4) will be updated and preserved. This queue has been incorporated into the generalized module model so that statistics, relating to transaction van residence times and population activity, could easily be extracted from the simulation study.

Once entered into the residence queue, the transaction will be directed, via the route control logic, to the capture queue of the first equipment needed. After entering the specific equipment capture queue a test is continually performed to ascertain both the availability of the particular equipment and a person to operate that equipment. When the test logic yields a positive result for man and machine, the transaction leaves the capture queue, siezes both man and machine and control transfers to the specific equipment model.

When the transaction has completed its equipment use, it releases both man and machine and, under direction of the route control, logic is placed in another equipment capture queue in the same van or be removed from the van (and consequently from the particular van residence queue) and placed in another van. In either case, the appropriate logic is invoked and the process continued until the product is complete.

When the particular requested product has been produced, it is returned to the Operations Module for quality control and distribution.

4.3.3 Generalized Equipment Model

A discussion of a generalized equipment model will be presented instead of a discussion of each equipment contained in the TSS. This

has been done because both the basic structure and the salient operating features of each of the equipment models are similar. In addition, the program source code listing is so heavily commented that an understanding of the basic equipment model will allow the reader to explore those equipment models of prime interest to himself. The basic GPSS logic flow of the generalized equipment model is depicted in Figure 4.8.

The first action to occur, when an equipment is captured by a transaction, is for the local iteration logic to analyze the attributes of the product request. The type of product is identified by reference to the transaction parameters that are associated with primary and secondary categories. Once the logic examines the attribute values and other logical conditions it assigns the loop counter a numeric value defining the number of times the equipment function is to be executed. For example, if the equipment were a photographic plate maker, the number of iterations (and consequently, the value of the loop counter) would be the number of plates to be made, to honor the requirements set forth by the parameters and attributes of the transaction.

Once the number of iterations is defined, the actual emulation of the real process would be accomplished. In the case of the platemaker, GPSS would sample from a random number generator and map the sample into a rectangular distribution with a mean of 300 seconds and a half width of 60 seconds. Therefore, the mapped time would be 5 minutes, plus or minus 1 minute, and would represent the time delay one would encounter installing, exposing and removing a plate from the equipment. Statistics are automatically gathered on the activity of the machine.

After completion of an iteration, the loop counter numeric value decremented and compared with zero. If all the iterations were completed, the transaction would free both captured equipment and server. Then, control would be assumed by the route control logic and the transaction would continue on its path through the system. If the iterations were not all complete, the transaction would circulate around the loop and the mapping process would begin again.

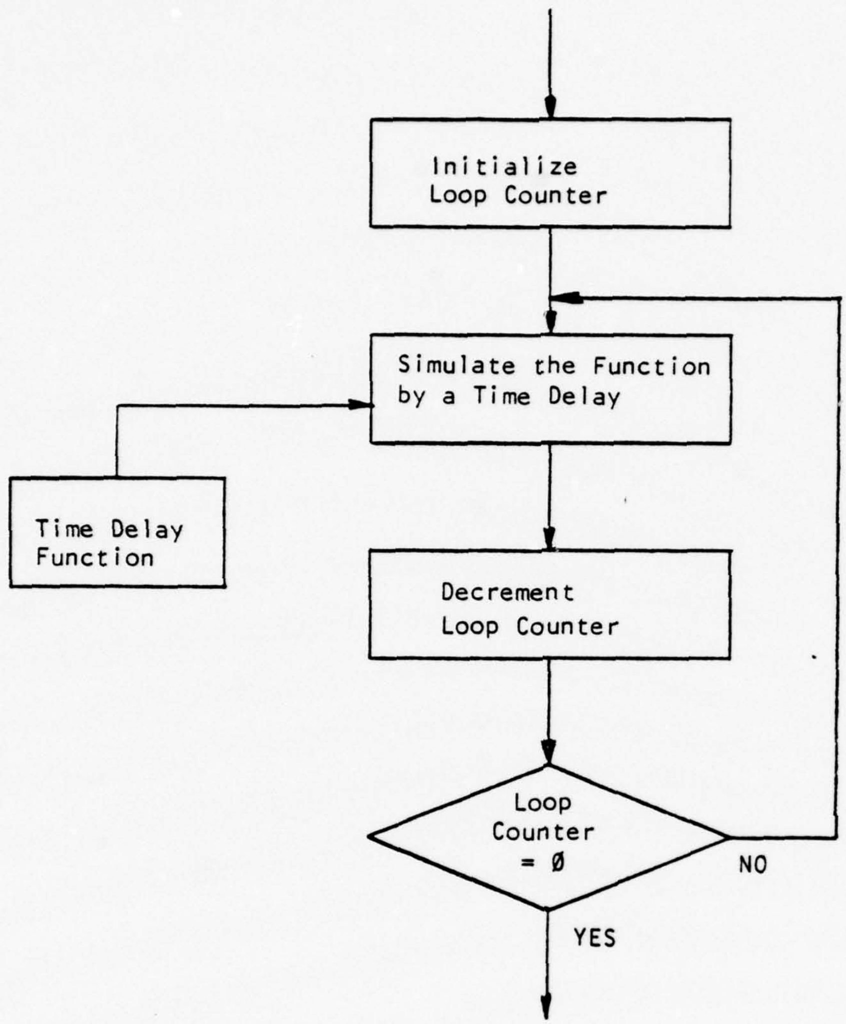


Figure 4.8 GENERALIZED EQUIPMENT MODEL

It should be obvious that this basic single function - single loop equipment model can be incorporated into more sophisticated, multi-loop/multi-function models, to emulate very complicated man-machine processes. This is what has been done in the development of the models of the TSS equipment complement.

4.3.4 Transaction Route Control

The control and guidance of product request transactions through the TSS is accomplished by the transaction route control logic. The transaction route control logic is essentially responsible for monitoring all transactions that are in existence, at any clock tick, while the simulation is in progress. When a transaction is freeing an equipment and server, the logic will examine the parameters and attributes of the transaction to determine two factors. These two factors are: (1) route control matrix row address, (2) route control matrix column address.

The remaining portion of the logic will retrieve the contents of the matrix location as specified by the row/column address, and then resolve the pre-determined packed information contained in the number into its three component parts:

1 - Van Designation
2 - Equipment Designation
3 - Logic Code

Subsequently, the logic uses this retrieve information to direct the transaction to its next designated van, and then its next designated equipment. The equipment model then uses the associated logic code to assign a value to the iteration loop counter. This process continues until the tour of the transaction through the TSS is complete.

This deterministic control structure was developed to assure that the path of the transaction through the model could easily be changed and that the path be essentially independent of the model topology. The developed logic performs well and allows the model user a flexibility generally not available in large system simulation models.

A copy of the entire source code used in the simulations reported herein is contained in Appendix G.

4.4.1 Simulation Supplied Statistics

The system model provides us with the following categories of output:

a) Clock Statistic
b) GPSS Statistics
c) Summary Statistics

The clock statistic is a listing of how many time units occurred during the simulation and of how long the simulation lasted. The time unit used in the simulation was a second. Seconds were chosen not because production times were accurate down to the second, but because variances in production times could easily be described, and in the long run, would produce more realistic statistics. The simulation was run for 144 hours, ie. 518,400 seconds.

The GPSS statistics can be divided into two parts:

a) Queue Statistics
b) Utilization Statistics

The queue statistics provided by the system model are:

a) <u>Queue Name</u> - designation of the queue.
b) <u>Maximum Contents</u> - the largest number of transactions waiting in the queue at the same time during the simulation.
c) <u>Average Contents</u> - average value of the queue content. It is equal to the sum of the times spent by all transactions in the queue, divided by the total simulation time.
d) <u>Total Entries</u> - the total number of transactions that have waited in the queue.
e) <u>Zero Entries</u> - the total number of queue entries that experienced no waiting.

f) <u>Percent Zeros</u> - percentage of total queue entries which experienced no waiting.

g) <u>Average Time/Transaction</u> - the average time that each transaction spent waiting in the queue (zero entries are included in this average).

h) <u>$Average Time/Transaction</u> - the average time that each transaction spent waiting in the queue (zero entires are excluded from this average).

i) <u>Current Contents</u> - the current number of transactions present in the queue.

The utilization statistics provided by the system model are:

a) <u>Storage Name</u> - designation of the storage.

b) <u>Capacity</u> - number of equipments or units of the storage that are available.

c) <u>Average Contents</u> - fraction of the simulation time in which the storage was used.

d) <u>Average Utilization</u> - the average contents divided by the storage's capacity which gives the fraction of simulation time for which each element of the storage was used.

e) <u>Entries</u> - the number of transactions that have utilized the storage.

f) <u>Average Time/Transaction</u> - the average time that each transaction spent utilizing the storage.

g) <u>Current Contents</u> - the current number of transactions present in the storage.

h) <u>Maximum Contents</u> - the largest number of transactions utilizing the storage at the same time during the simulation.

In addition to the GPSS statistics which were automatically generated, summary statistics were generated using logic written by Decilog. These statistics summarize the TSS's performance and include:

a) Transaction Parametric History Matrix

b) Transaction Temporal History Matrix

c) Transaction Cumulative Summary Matrix

4.4.2 TSS Statistical Interpretation

To further explain the simulation statistics defined in the previous section, examples of these statistics will be discussed.

An example of GPSS generated queue and utilization statistics is shown in Figure 4-9. These statistics are a "snapshot" of the system and can be taken at any time during the simulation. Note that the GPSS generated statistics are cumulative to that point in time in which they are printed out. The example in Figure 4-9 illustrates the statistics generated for the Plate Processing Module and its various equipment at the end of the 144-hour (or 518,400 second) simulation.

To begin with, the Queue Name column of the Van Input and Equipment Queue Statistics designates the names of the queues for the van and each piece of equipment. For example, PMK18 is the queue name for the Platemaker found in the Plate Processing Module.

The next column, Maximum Contents, gives us the largest number of transactions to wait in a specific queue, at one time, during the simulation. Using the queue PMK18, for example, its Maximum Contents was 2.

Average Contents derives its value from dividing the sum of the times of all the entries of the queue by the total simulation time. This Average Contents value is, in effect, the expected number of transactions to be present in the queue, at any one instant in time, during the simulation. For queue PMK18, we find an Average Contents value of .019. Thus, at any given time during the simulation, we could expect there to be, on the average, .019 transactions in the queue PMK18.

Total Entries is a count of how many transactions entered the queue during the simulation. In our example, queue PMK18, there were 38 entries.

Zero Entries is a count of how many transactions entered the queue and did not have to wait. In queue PMK18, we see of the 38 total entries, there were 32 zero or non-waiting entries.

PLATE PROCESSING MODULE (REPRO)

VANR INPUT AND EQUIPMENT QUEUE STATISTICS -

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRAN	$AVERAGE TIME/TRAN	CURRENT CONTENTS
VAN18	5	0.403	38	0	0.0	5491.395	5491.395	0
PMK18	2	0.019	38	32	84.2	264.368	1674.333	0
LPS18	3	0.022	38	33	86.8	305.684	2323.200	0
PFT18	1	0.000	38	38	100.0	0.000	0.000	0

VANR SERVER UTILIZATION STATISTICS -

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
SRV18	4	0.361	0.090	144	1640.447	0	4

VANR EQUIPMENT UTILIZATION STATISTICS -

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
PMK18	1	0.106	0.106	38	1449.474	0	1
LPS18	2	0.212	0.106	38	2887.711	0	2
PFT18	2	0.043	0.021	38	584.158	0	2

FIGURE 4-9

Percent Zeros lists the percentage of total queue entries which were zero entries. For PMK18, 84.2% of the total entries were zero entries.

Average Time/Transaction is the average time that a transaction waits in a queue. This average includes the zero waiting times of the zero entries. For PMK18, the Average Time/Transaction is 264.368 secs.

$Average Time/Transaction is the average time that a transaction which must wait, (non-zero entry), waits in a queue. This average excludes zero entries so that only transactions with waiting times are averaged together. This average value is normally higher due to the omission of the zero entries. In this case, PMK18, the $Average Time/Transaction is 1674.333 secs.

Finally, the Current Contents column gives the number of transactions currently present in the queue. For the queue PMK18, we find there are no transactions waiting in the queue at the present time.

The next grouping of GPSS statistics are the utilization statistics. Looking at the Equipment Utilization Statistics section of our example, the Storage Name column designates the name of the "storage" that represents the piece of equipment; for example, PMK18.

The Capacity column tells us the number of elements or equipments that are available in the storage. In PMK18, we find a Capacity of one, so there is only one piece of equipment available in that storage.

Average Contents derives its value from dividing the sum of all the times during which the storage was utilized by the total simulation time. This Average Contents value is, in effect, the fraction of the simulation time in which the storage was used. PMK18, for example, was used .106 or 10.6% of the total simulation time.

Average Utilization is the Average Contents of a storage divided by its Capacity (number of elements). This value would then be the fraction of simulation time for which each element of the storage was used. In PMK18, the Capacity is one so that its Average Utilization is .106.

The Entries column is a count of how many transactions entered and used the storage. In our example, PMK18, 38 transactions utilized the storage.

Average Time/Transaction is simply the average time that each transaction has spent utilizing the storage. The Average Time/Transaction in PMK18 is 1449.474 secs.

The Current Contents is a count of the number of transactions currently utilizing the storage. In the example, there are zero transactions now utilizing PMK18.

Finally, the Maximum Contents column tells us the largest number of transactions utilizing the storage at the same time during the simulation. For PMK18, there was a maximum of one transaction present at any one time during the simulation because there was only one PMK18.

To summarize the TSS's performance, three tables of statistics were generated.

The first of these is the Transaction Parametric History Matrix. This matrix gives a listing of all transactions that have been requested during the simulation and their corresponding attributes. This matrix is structured in the following manner:

TRANSACTION PARAMETRIC HISTORY MATRIX

Matrix Entry Definitions -

Column (1) - Transaction Arrival Number
Column (2) - Primary Category Number
Column (3) - Secondary Category Number
Column (4) - A Attribute Value
Column (5) - B Attribute Value
Column (6) - C Attribute Value
Column (7) - D Attribute Value

Column (8) - E Attribute Value

Column (9) - Currently Unused

Column (10) - Currently Unused

An illustration of the first six rows (transactions) of the output follows:

HALFWORD MATRIX PSM (Parametric History Matrix)

ROW/ COLUMN	1	2	3	4	5	6	7	8	9	10
1	1	4	4	4	1	1	1	1	0	0
2	2	1	1	1	1	1	1	1	0	0
3	3	2	4	1	1	1	1	1	0	0
4	4	2	4	1	1	1	1	1	0	0
5	5	1	1	4	1	1	1	1	0	0
6	6	7	2	4	1	2	16	1	0	0

As an example, the first transaction has a Primary Category number of 4 and a Secondary Category of 4. The attributes describing this transaction are then listed in the subsequent columns. Thus, the Transaction Parametric History Matrix is a record of the TSS input.

The next summary listing is the Transaction Temporal History Matrix. This matrix gives a listing of the transactions that the TSS completed during the simulation and their pertinent production times. This matrix organizes transactions in order of their completion and is structured in the following manner:

TRANSACTION TEMPORAL HISTORY MATRIX

Matrix Entry Definitions -

Column (1) - Transaction Arrival Number

Column (2) - Primary Category Number

Column (3) - Secondary Category Number

Column (4) - Transaction Entry Time (Hrs - Portion)
Column (5) - Transaction Entry Time (Min - Portion)
Column (6) - Transaction Exit Time (Hrs - Portion)
Column (7) - Transaction Exit Time (Min - Portion)
Column (8) - Transaction Residence Time (Hrs - Portion)
Column (9) - Transaction Residence Time (Min - Portion)
Column (10) - Transaction Travel Time (Parts/10000)

An illustration of this first six rows (transactions) of the output follows:

HALFWORD MATRIX TSM

ROW/ COLUMN	1	2	3	4	5	6	7	8	9	10
1	2	1	1	0	49	4	44	3	56	33
2	10	1	1	3	40	5	28	1	48	73
3	11	1	1	4	21	5	50	1	29	89
4	13	1	1	4	28	6	35	2	7	63
5	14	6	2	4	52	6	37	1	46	75
6	5	1	1	1	46	7	57	6	10	21

The first transaction to be completed was the second transaction to enter the TSS. From columns two and three we see that the product has a Primary Category number of one and Secondary Category number of one. The columns that follow list important times concerning production. Columns four and five contain the time at which a transaction enters the TSS. Columns six and seven list the time at which a transaction exits the TSS. Columns eight and nine contain the total time in which a transaction resides in the TSS. Column ten lists the portion of the residence time in which a transaction spends in transit within the TSS. Thus, the Transaction Temporal History Matrix is a record of TSS output.

The final summary listing is the Transaction Cumulative Summary Matrix. This matrix lists each product type by each priority level with their pertinent production times. This matrix is structured in the following manner:

TRANSACTION CUMULATIVE SUMMARY MATRIX

Matrix Entry Definitions -

Column (1) - Primary Category Number
Column (2) - Secondary Category Number
Column (3) - C Attribute Value
Column (4) - Number of Times Entered (Absolute)
Column (5) - Portion of Total Entries (Parts/10000)
Column (6) - Number of Times Exited (Absolute)
Column (7) - Portion of Total Exits (Parts/10000)
Column (8) - Average Residence Time (Hrs - Portion)
Column (9) - Average Residence Time (Min - Portion)
Column (10) - Average Travel Time (Parts/10000)

An illustration of Product 1-1 and its three levels of priority described in the form shown above, follows:

ROW/ COLUMN	1	2	3	4	5	6	7	8	9	10
1	1	1	0	9	220	3	120	25	2	24
2	1	1	1	127	3112	124	5000	6	2	19
3	1	1	2	19	465	19	766	2	34	66

Column three denotes the priority level; the higher the number, the higher the priority. Columns eight and nine list the average residence time that a product of a certain priority level spends in the TSS. Note that as the priority level of a product increases, the average residence time, ie. production time, decreases. Thus, the Transaction Cumulative Summary Matrix is a record of TSS throughput.

5.0 Conclusions & Recommendations

Four comparable simulation experiments were performed. These were:

1. January, 1978 T.D.P.
2. Same as 1 with doubled Drafting, doubled Rectifier I, and Camera Modules.
3. Decilog modified version, described below.
4. Same as 3 with Interactive Graphics System substituted for one Drafting Module and an Analytical Stereoplotter added to Rectifier.

The following sections describe the results of each simulation in chronological order, and a later section will show numerical comparisons among all configurations. All simulations were run with identical product requests at a rate of three per hour.

5.1 January, 1978 T.D.P. Simulation

Decilog was instructed to simulate the Corps TSS as consisting of one each of the individual Modules, except Press, of which four were included. This yielded a total of 23 Modules.

"Bottlenecks" were defined as equipments which generated a queue of twenty or more transactions. Undercapacity was defined as an equipment which was utilized more than 67% of the time. Table 5-1 lists the equipments, by Module, which met either or both of these criteria at the end of 144 hours.

TABLE 5-1 HIGH TRAFFIC RESISTANCE - JAN. 1978 T.D.P.

MODULE & EQUIPMENT	QUEUE LENGTH	UTILIZATION (%)
Drafting		
4 Drafting Tables	21	34.4
Light Table	10	92.0
Synthesis		
Light Table	21	95.5
Rectifier I		
Auto. Film Processor	6	67.0
Rectifier II		
APPS	12	96.0
Photomechanical		
Photoprocessing Machine	17	72.1
Camera		
Copy Camera	55	96.0

The above results were communicated to the Engineer Topographic Laboratory and Decilog was directed to double capacity in:

- Drafting
- Rectifier I
- Camera

5.2 Modified January 1978 T.D.P. Configuration

The effect of including 2 Drafting Modules, 2 Rectifier I Modules and 2 Camera Modules in the second simulation was to increase the total module count to 26.

The results of this module increase are shown in Table 5-2.

TABLE 5-2 HIGH TRAFFIC RESISTANCE MODIFIED JAN. 1978 T.D.P.

MODULE & EQUIPMENT	QUEUE LENGTH	UTILIZATION (%)
* Drafting		
8 Drafting Tables	6	32.5
2 Light Tables	5	89.4
Synthesis		
Light Table	19	95.2
* Rectifier I		
2 Auto. Film Processors	4	47.2
Rectifier II		
APPS	17	96.0
Photomechanical		
Photo Processing Machine	13	64.5
* Camera		
Copy Camera	54	93.6

TABLE 5-2 (cont'd)

* Indicates Module Doubled

A detailed analysis of the differences between the original and modified versions was carried out. In the Drafting area, the light table utilization remained excessive, however, queues for both drafting tables and light tables was acceptable. It was found that, by reorganizing these Modules to increase the number of light tables and decreases the number of drafting boards, there should be no problem with Drafting.*

The relatively low drafting table utilization apparently was due to a shortage of personnel in Drafting, and it was recommended that the number be increased.

Both Rectifier I and Photomechanical fell out of the problem range, based on the above stated criteria. In the case of Rectifier I this was a straightforward result of doubling. In the case of the Photo Processing Machine, however, the result is more subtle.

Although the Photo Processing Machine Utilization is still high, it fell within the acceptable range. This was due to the addition of the Automatic Film Processor in Rectifier I, and surprisingly (at the time) because of the fact that, when Rectifier I was doubled, an additional Printer/Enlarger was introduced into the TSS. These two equipments took some of the load off the Photo Processor Machine, and led to further analysis of the results which will be discussed below.

Rectifier II, which was not doubled, remained excessively high in Utilization and shows an increased queue. The increased queue is due to the fact that more requests worked their way through the TSS, and were ready for APPS processing.

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* Subsequently, and independently, the IEET replaced drafting boards with light tables, and increased the Module count to three. This new configuration will be simulated in the near future.

Despite the fact that two Copy Cameras were now available, the Copy Camera queue remained essentially constant, ie. 55 vs. 54.

Total Throughput, of course, increased. Table 5-3 shows the total number of requests served for each equipment for the original and the modified T.D.P.'s.

TABLE 5-3 THROUGHPUT AT CRITICAL EQUIPMENTS

NO. PRODUCTS PROCESSED	ORIGINAL	3 MODULES DOUBLED
* Drafting		
Drafting Tables	11	22
Light Table(s)	16	39
Synthesis		
Light Table	52	55
* Rectifier I		
Printer/Enlarger	58	85
Auto. Film Processor	66	94
Rectifier II		
APPS	15	19
Photomechanical		
Photo Processing Machine	55	62
* Camera		
Copy Camera	6	16

* Indicated Doubled.

The large increase in requests served by the Printer/Enlarger, which had not been a high resistance equipment in the unmodified version, pro-

vided a clue for further analysis. It was determined that many requests involving Image Based Products were recirculating among the same pieces of equipment, and, were, consequently, delayed and re-delayed in queues.

This fact led the authors to the conclusion that, by reorganizing the locations of equipment within sub-systems, a more product-oriented and more efficient TSS design could be achieved. With the concurrence of ETL, the changes to the TSS design described in the next section were incorporated.

5.3 Version "B" TSS Configuration

The following, minor, changes in the TSS equipment list and configuration were made. In all cases where equipment was added, it was determined that the equipment fit comfortably in the Modules. In fact, more free floor space was available with the reconfiguration.

1. Retain double Drafting.

2. Rectifier I: add one Frame Rectifier. Retain 2 Modules.

3. Rectifier II:
   a) delete 3 drafting/light tables to make room for equipment to be added. (These previously had very low utilization).
   b) add one Automatic Film Processor
   c) add one Printer/Enlarger
   d) add one Copy Camera

4. Camera
   a) delete one (of two) Copy Cameras
   b) add one Printer/Enlarger
   c) add one Automatic Film Processor

5. Synthesis: add one light table.

A review of the above changes will reveal that the IBP subsystem and the REPRO subsystem have been given redundant capabilities. The TSS is thus more product-oriented. Time is not wasted unnecessarily from Module to Module, and a greater degree of flexibility is available in subsystem and Module deployment.

This TSS configuration, Version "B", or the Decilog modified configuration was then simulated under exactly the same conditions as Version A, and the results for the critical equipments are shown in Table 5-4.

TABLE 5-4 HIGH TRAFFIC RESISTANCE - DECILOG MODIFIED TSS

MODULE & EQUIPMENT	QUEUE LENGTH	UTILIZATION (%)
Synthesis		
* 2 Light Tables	7	90.2
Drafting		
8 Drafting Tables	0	57.6
2 Light Tables	16	91.5
Rectifier I		
Printer/Enlarger	0	15.4
Automatic Film Processor	11	35.7
Rectifier II		
APPS	4	85.2
Automatic Film Processor	0	5.5
Printer/Enlarger	0	2.2
Copy Camera	0	8.7
Camera		
Copy Camera	49	96.0
Printer/Enlarger	0	14.5
Automatic Film Processor	0	35.9

Drafting, having remained essentially the same, the comments regarding modified Version A above, apply. The Image Based Products problems have essentially disappeared. The serious problem with the Copy Camera in Camera, remains. However, it should be obvious that, an intelligent commander would route some Copy Camera requests to Rectifier II, thus relieving this problem.

In addition to the above, ETL wished to simulate the effect of adding an Interactvie Graphics System (IGS) to Drafting, and an Analytical Stereoplotter (ASP) to Orthophoto. This was done, and is described in the next section.

5.4 Version "B" with IGS and ASP

One of the existing Drafting Modules was deleted, and replaced by an IGS. In addition, an ASP was added to Orthophoto, however, no APPS were deleted. The results of this simulation are shown in Table 5-5.

TABLE 5-5 HIGH TRAFFIC RESISTANCE
VERSION "B" WITH IGS & ASP

MODULE & EQUIPMENT	QUEUE LENGTH	UTILIZATION (%)
Synthesis		
2 Light Tables	11	90.4
Drafting I		
4 Drafting Tables	0	60.9
Light Table	1	91.5
Drafting II		
2 IGS	8	92.6
Tracing Table	1	73.0
Rectifier I		
Printer/Enlarger	0	15.4
Automatic Film Processor	11	35.7

TABLE 5-5 (cont'd)

MODULE & EQUIPMENT	QUEUE LENGTH	UTILIZATION (%)
Rectifier II		
APPS	4	64.1
Automatic Film Processor	0	11.0
Printer/Enlarger	0	4.4
Copy Camera	0	16.9
Orthophoto		
ASP	4	77.6
Camera		
Copy Camera	53	96.0
Printer/Enlarger	0	14.4
Automatic Film Processor	0	36.0

The results are very similar to those for Version "B" without the IGS and ASP. With regard to production rate, the ASP definitely increased throughput and relieved the APPS load slightly. The IGS had slightly counterproductive effects on Drafting. However, it had been assumed that a Digital Data Base was not available for the IGS, and, hence, had to be developed for each request. Since this is very time consuming, it is likely that, if the data base were deployed with the IGS, throughput would be increased.

Table 5-6 shows throughput for Version "B" both with and without IGS and ASP.

TABLE 5-6 THROUGHPUT - VERSION "B"

CRITICAL EQUIPMENTS	NO. REQUESTS SERVED W/O IGS & ASD	NO. REQUESTS SERVED WITH IGS & ASP
Synthesis		
2 Light Tables	94	95
Drafting I		
4 Drafting Tables	20	39
1 Light Table	14	35
Drafting II		
2 IGS	-	25
Rectifier I		
Printer/Enlarger	35	27
Automatic Film Processor	43	41
Rectifier II		
APPS	14	22
Automatic Film Processor	18	18
Printer/Enlarger	16	16
Copy Camera	18	18
Orthophoto		
ASP	-	16
Camera		
Copy Camera	7	8
Printer/Enlarger	40	40
Automatic Film Processor	40	40

As stated above, there is little difference between Version "B" with and without IGS and ASP under the assumptions made.

5.5 Overall Comparison of Systems Simulated

There is no question as to the superiority of Version B over Version A. Since this was only a minor modification toward a Product Oriented TSS, it is concluded that further work in this direction could lead to increased efficiency, lower module count and enhanced deployment flexibility.

None of the systems simulated could be considered a "quick-reaction" system. It is considered highly likely that a Product-Oriented system, with some thought toward optimization, could meet the R.O.C. requirements.

Table 5-6 shows the per cent of requested products completed at the end of 144 hours for Version A-1, (Original January, 1978 T.D.P.); A-2, (Modified January T.D.P.); B-1, (Decilog modified configuration); and B-2, (Decilog configuration with IGS and ASP).

TABLE 5-6 % OF COMPLETED PRODUCTS AT 144 HRS.

PRIMARY CATEGORY	VERSION A-1	VERSION A-2	VERSION B-1	VERSION B-2
1	63.6	63.9	66.1	61.5
2	33.3	36.2	69.1	55.6
3	4.2	8.0	38.7	37.5
4	0	4.5	0	0
5	100	100	100	100
6	80	80	80	80
7	0	0	7.7	0
8	52.1	40.8	52.9	52.8
SYSTEM THROUGHPUT EFFICIENCY	50.5	49.9	58.8	53.9

The absolute values in this table should not be relied on, because it includes requests entered toward the end of the 144 hour period, which could not possible have been completed. For example, in Version B-2, Category 3, 37.5% of all products represents 60% of the expected value of this category which would have been completed, had no delays been encountered. In addition, Version A-2, for example, accepted 22 more requests than Version A-1, and the absolute number of finished products was 14 more than A-1.

The last row in the table, "System Throughput Efficiency", is a valid relative comparision of the versions simulated. It is concluded that a Product Oriented System would be most efficient. If the Digital Data Base were available, it is probable that Version B-2 would not differ significantly from Version B-1.

The reader interested in the detailed statistics is referred to in Appendix H. This appendix contains the print-out of all statistics for all four versions run. These statistics are in easily read form, and were generated by both the GPSS Report Generator and also specially prepared Report Generator Routines.

5.6 Recommendations

Since the final IEET recommendations as to TSS configuration were made at the same time that the work reported herein was completed, it is recommended that this highest priority be given to a simulation of this configuration. This configuration consists of 34 modules. This simulation should also have the capability of varying the number of personnel per module to resolve the staffing problems encountered to date.

Consideration should be given to a reconfiguration of the TSS to make the system more product-oriented. This should result in reduced module count, lower cost, enhanced deployment capability and increased efficiency.

If it is felt that a digital data base will be deployed with the TSS, the simulation should be re-run, assuming the data base. This would have a significant effect on throughput.

The model should be modified to include intelligence in the Route Control Matrix. This intelligence should allow parallel processing of all requests. In Version B, the logic was developed to allow some parallel paths, based upon earliest product completion it is recommended that this be included for all products.

IED

78